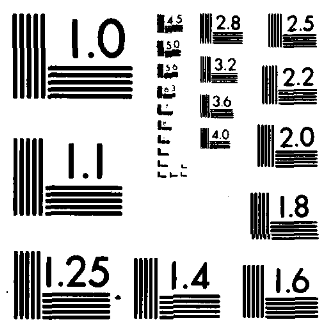
AD-A089 053 FEDERAL AVIATION ADMINISTRATION TECHNICAL CENTER ATL--ETC F/G 1/7
PRECISION L-BAND DME TESTS.(U)
AUG 80 H POSTEL
UNCLASSIFIED FAA-CT-80-25 FAA-RD-80-74 NL

1 OF 1
AD-A
089053

END
DATE
FILMED
10-80
DTIC



MICROCOPY RESOLUTION TEST CHART

Report No. FAA-RD-80-74
FAA-CT-80-25

LEVEL II

(12)

PRECISION L-BAND DME TESTS

AD A089053

Harold Postel

FEDERAL AVIATION ADMINISTRATION TECHNICAL CENTER
Atlantic City, N. J. 08405

INTERIM REPORT

AUGUST 1980

Document is available to the U.S. public through
the National Technical Information Service,
Springfield, Virginia 22161.

Prepared for

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D. C. 20590

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-RD-80-74	AD-A089053	

4. Title and Subtitle	5. Report Date
PRECISION L-BAND DME TESTS	Aug[redacted]80
	6. Performing Organization Code
	8. Performing Organization Report No.
7. Author(s): Harold Postel	FAA-CT-80-25
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Federal Aviation Administration Technical Center Atlantic City, New Jersey 08405	11. Contract or Grant No. 075-725-210
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation Federal Aviation Administration Systems Research and Development Service Washington, D.C. 20590	Interim rept. May [redacted] Nov[redacted]78
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This phase of the project was performed under Technical Program Document (TPD) 04-109, subprogram 075-725-210. The report covers the findings on system accuracy and stability of the L-Band Precision Distance Measuring Equipment (PDME). The results showed differences in bias under varying conditions of approaches, orbits, radials, and river runs. The 24-hour overall stability of the system was recorded. Further testing should be performed with simulators that have the desired accuracy required for testing a PDME system so that a baseline can be established.

17. Key Words	18. Distribution Statement
L-Band Precision Distance Measurement Equipment Precision Interrogator Flight Test Antenna Height	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	40	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

411263

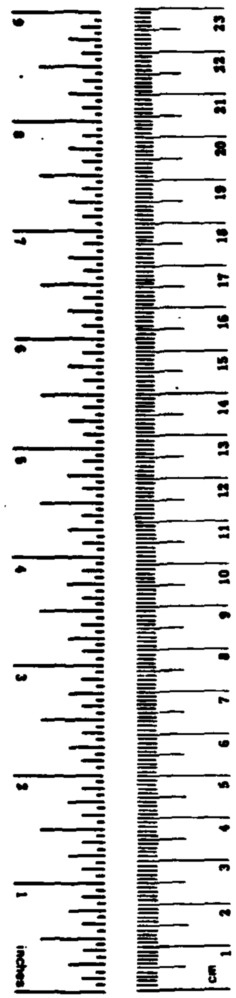
JOB

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

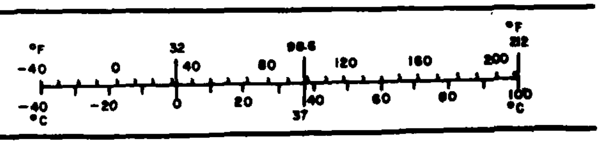
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10 286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

The author wishes to acknowledge Mr. Ron Polillo of the Range Programming and Analysis Branch, ACT-750, who was responsible for the programming which generated the flight plots in this report.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

PURPOSE

The purpose of this project was to determine the system accuracy of L-Band Precision Distance Measuring Equipment (PDME) utilizing a modified Aerocom model 5351A DME ground transponder.

BACKGROUND

The Federal Aviation Administration (FAA) Technical Center, in coordination with the Systems Research and Development Service (SRDS), tested a C-band DME for range measurement accuracy in accordance with Radio Technical Commission for Aeronautics (RTCA) specifications prepared by the Special Committee, SC-117. Previous testing in 1974 at the Technical Center and Crows Landing, California, showed that an L-band DME would be simpler and more economical to implement (related final report, Contract No. WI-74-1245-1, "Experimentation for Use of L-Band DME with the Microwave Landing System," April 1974).

These 1974 tests resulted in the selection of a cos/cos^2 shaped pulse for Microwave Landing System (MLS)/(L-Band) DME. The Bendix Avionics Division, in coordination with Aerocom, modified a standard model 5351 DME ground transponder to operate specifically as a DME system applicable to MLS/DME. The design also provides the necessary stability and an overall accuracy of 100 feet (2 sigma), which was incorporated into the specification, when used with the Bendix airborne MLS/DME interrogator. The Aerocom DME is one of several ground transponders undergoing accuracy tests.

DESCRIPTION OF EQUIPMENT

The Aerocom 5351A DME was modified for MLS/DME operation and redesigned to provide a first pulse output of a cos/cos^2 wave shape and a second pulse of a cos^2 wave shape. The first pulse provides a fast rise time on the start of the pulse and a cos^2 shape for the rest of the pulse. Designers increased the ground receiver band width from 0.35 megahertz (MHz) to 3.5 MHz to pass the higher frequencies of the cos/cos^2 wave shape transmitted for the airborne interrogator.

To optimize the DME accuracy of the ground transponder, the reply delay is automatically maintained by the system signal generator as a source pulse, thus automatically maintaining system reply delay. In the normal configuration, an identification keyer is provided. The keyer was not utilized during this test.

TECHNICAL APPROACH

To determine the accuracy of an L-Band PDME several tests were conducted. Three primary areas were tested:

1. Static Tests. These tests were conducted utilizing a mobile van with an adjustable antenna mast. The van collected data at specially surveyed test points (TP) to determine accuracy at various antenna heights and distances from the PDME.

2. Stability Tests. To determine the overall accuracy of the PDME system over a period of time, a calculator programmed to take a specified number of samples was used. An error mean and error standard deviation was obtained from the results.

3. Flight Tests. Test flights consisting of orbits, radials, and approaches were made to determine the system accuracies under varying flight conditions. Tracking to obtain absolute accuracy was performed by use of a Sylvania mobile laser tracker.

TEST CONFIGURATION

Van instrumentation (shown in figure 1) was used to collect static data at all TP's (see figure 2). DME information for accuracy was collected at several surveyed TP's located on taxiway "B" parallel to runway 13/31.

The programmed Hewlett Packard 9830 calculator (figure 1) was used to collect samples of size 200 DME range error data at each of nine antenna heights at each test point shown in figure 2. The mean and standard deviation of each sample were then calculated.

Technicians positioned the adjustable antenna tower, mounted on the rear of the test van, over the surveyed test points. The antenna height varied from 45 to 5 feet in 5-foot increments. A calibrated meter with a light-emitting diode (LED) readout attached to the antenna mast measured the exact height above each test point.

The airborne interrogator, a Bendix MLS/DME precision interrogator system, is designed to function as a navigational aid while en route, and to provide precise MLS/DME range upon arrival at the airport. From 0 to 5 nautical miles (nmi), which is the range of the MLS/DME precision mode, system accuracies are specified to be ±50 feet (2 sigma). Beyond 5 nmi, during normal mode operation, accuracies are ±0.1 nmi or 0.2 percent of the indicated range.

Because accurate airborne interrogator test equipment was not available, a TS-101C tactical air navigation aid (TACAN) simulator was utilized to operationally check the airborne interrogator.

The video output of the Bendix airborne receiver was monitored visually to note any unusual occurrences during the test, such as susceptibility to multipath and erroneous range indication.

STABILITY TESTS

Tests were made to determine if any significant changes in stability occurred over a period of time that would adversely affect the transmittal of distance information. A block diagram of the test setup utilized is shown in figure 3. A 9830 Hewlett Packard calculator programmed to accept 1,000 samples of DME information during each 2-minute period produced, from the samples, an error mean and error standard deviation.

Using table 1, a series of four tests were made with the three receivers. In the series, technicians adjusted the signal input to the interrogator receiver in upward steps at approximately -45 decibels above 1 milliwatt (dBm), -60 dBm, -65 dBm, and -77 dBm. To reach the desired signal level for each receiver, testors read the automatic gain control (AGC) voltage meter, while adjusting the attenuator, until the desired level was reached, as interpreted from figure 4. The plots shown in figure 4 were obtained by injecting a signal from the TS-101C simulator and recording the corresponding AGC voltage. The plots were utilized in formulating the data shown in table 1.

FLIGHT TESTS

The airborne instrumentation package (figure 5), which consists of a Kennedy 7-track recorder, real-time clock interface, and a Bendix MLS/DME airborne interrogator was installed on a Convair 580 for flight test data collection. The instruments collected data during orbits, approaches, "river runs," and selected radials at the Washington National Airport, Washington, D.C. At the airport, a Sylvania mobile laser tracking system recorded data on the aircraft position to an accuracy of ±1 foot for 0-5 nmi, ±2 feet for 5-10 nmi, and ±5 feet for 10 to 25 nmi.

TABLE 1. INTERROGATOR TESTS

Test	Interrogator Serial No.	Distance to Transponder (ft)	Sample Pilot Readout nmi (ft)	Mean Error (ft)	Standard Deviation (ft)	AGC Volts	Interrogator Input dBm	Interrogator Input Mode
1	109	9700	1.60 (9730)	31.96	7.58	1.31	-46	Precision
	104	9700	1.61 (9767)	66.59	11.38	0.38	-45	
	103	9700	1.61 (9761)	62.13	22.66	1.11	-46	
2	109	9700	1.60 (9718)	18.90	15.48	1.85	-62	
	104	9700	1.62 (9791)	88.89	18.33	0.88	-63	
	103	9700	1.59 (9712)	9.57	17.11	1.52	-58	
3	109	9700	1.60 (9721)	20.94	14.60	1.81	-65	Normal
	104	9700	1.61 (9774)	74.25	19.93	1.07	-65	
	103	9700	1.61 (9756)	57.75	19.32	1.71	-68	
4	109	9700	1.60 (9718)	17.86	36.26	2.17	-77	
	104	9700	1.62 (9812)	112.07	40.95	1.36	-76	
	103	9700	1.61 (9791)	90.07	50.13	1.99	-78	

STATIC TEST RESULTS

Static test results include laboratory tests made in building 301 and those made at test points on the airport. Figure 6 shows sample plots of static accuracy data recorded at the surveyed test points TP-90 and TP-108 (shown in figure 2). Based on reflectometer measurements, a total of 186 feet was subtracted from the error data to correct for the 125-foot length of cable between the receiver and the antenna. The results of which show an average mean error of ±50 feet and a standard error deviation of ±5 feet for all pole heights and test points.

No range errors due to reflections or other abnormalities were observed during this test. The signal strength ranged from -36 dBm at test point 90 at an antenna height of 15 feet, to a low of -85 dBm at test point 108 with the antenna at 10 feet above the surveyed test point. Figure 7 is a plot of the signal strength versus the pole height of the antenna to the test van antenna, at various heights and at two different test points, TP-90 and TP-116. A signal level of -36 dBm would be representative of the MLS/DME interrogator in the precision mode.

Three interrogator receivers were tested to determine if significant changes in the system accuracy occurred between them. A change of ±50 feet is considered significant. Table 1 is a comparison of the readouts a pilot would see and the calculated error means and standard deviations. The data in the table shows that a variation of 79 feet in mean error of system accuracy did occur between different interrogators while in the precision mode, and 95 feet in the normal mode. This variation was obtained by subtracting the high mean error and low mean error in both the precision and normal modes. Receiver sensitivity in the MLS precision and normal modes is -60 dBm and -80 dBm, respectively.

FLIGHT TEST RESULTS

Test results for each type flight are tabulated in table 2. Where appropriate, path following range error statistics are calculated for both 0 to 5 and 5 to 10 nmi for each flight type. In addition, summary range error standard deviation is calculated for each flight type. No determination could be made as to the cause of shifts in bias from approximately 200 feet on March 28, 1979, to approximately 10 feet on July 9, 1979. Although there were variations in bias, the overall system accuracy of the collected DME data, with all bias removed, was as shown in table 3. The error values were calculated by using all data of each type of flight. Bendix engineers investigated the significant decrease in error means in the July data, but could not find the cause. Manufacturer's equipment specifications set processing accuracy of ±35 feet bias (-10 to -50 dBm) and ±30 feet for noise (standard deviation). The length of cable in the aircraft was not deducted from the calculations.

Figure 8 shows sample plots of data collected during the Washington National Airport test flights. Scatter plots, figure 9, show individual point plots of filtered data with bias removed (zero means) of all runs of each type flight.

To determine system accuracy, MLS/DME precision equipment design required that data be separated into two bins; 0 to 5 nmi and 5 to 10 nmi. The first bin contains precision mode data, while the second bin contains nonprecision mode data. Histogram plots required bin data to be grouped. In this instance, 0.5 nmi increments were selected. Plotted by flight type and bin range, histograms of figure 10 show error distribution with zero means. The summary standard

TABLE 2. FLIGHT TEST DATA TABULATION OF RANGE ERROR

Type of Flight	Flight Date	0 - 5 nmi Mean $\overline{X}$	0 - 5 nmi Standard Deviation	0 - 5 nmi No. of Data Pt. n	5 - 10 nmi Mean $\overline{X}$	5 - 10 nmi Standard Deviation	5 - 10 nmi No. of Data Pt. n
Approaches	3/28/79	189.595	6.686	278	258.925	68.285	123
	3/28/79	186.987	6.742	275	219.906	39.754	200
	3/28/79	191.361	14.438	470	201.825	79.193	172
	4/30/79	295.853	12.485	441	277.529	62.895	373
	4/30/79	289.325	19.746	282	261.340	101.883	466
	7/9/79	15.516	8.972	982	9.060	16.503	512
	7/9/79	10.385	5.349	157	15.571	14.072	104
Orbits	5/1/79	--	--	--	316.406	36.103	479
	5/1/79	--	--	--	148.310	16.015	449
	7/3/79	--	--	--	40.211	49.068	137
	10/25/79	--	--	--	57.905	49.612	1248
Radials	3/28/79	173.332	2.762	134	182.104	19.580	94
	4/30/79	276.710	7.832	69	278.803	9.729	197
	4/30/79	270.639	2.510	82	264.119	19.047	135
	7/3/79	128.322	2.501	41	133.456	9.041	165
	7/3/79	129.384	4.551	200	132.526	17.234	560
River Runs	3/28/79	186.089	4.395	483	200.888	40.919	325
	4/30/79	293.577	6.098	258	285.399	11.301	278
	7/3/79	61.239	1.520	73	53.008	11.439	121
	7/9/79	21.551	8.902	193	-4.398	25.269	68
	7/10/79	73.297	8.978	1110	55.839	43.979	205
All Approaches	--	--	9.129	2885	--	42.649	1950
All Orbits	--	--	--	--	--	41.714	2313
All Radials	--	--	2.935	526	--	12.031	1151
All River Runs	--	--	3.776	2117	--	18.255	997

TABLE 3. FLIGHT TEST DATA SUMMARY

Type of Flight	Range Error Std Deviation (ft) 0 to 5 nmi	Range Error Std Deviation (ft) 5 to 10 nmi
Approaches	±9	±42
Orbits	No Data	±42
Radials	±3	±12
River Runs	±4	±18

deviations of table 2 relate to these plots. These are normal distributions. Identification keyer effect was not determined on DME transponder accuracy.

STABILITY TEST RESULTS

The data shown in figure 11 were calculated from data collected in the MLS laboratory in building 301. The 9830 Hewlett Packard calculator was programmed to accept 1,000 samples of DME information each 2-minute period for approximately 20 hours, and then produced a mean and standard deviation. Five of the means were averaged to produce a mean of the differences and a standard deviation. The plot shown in figure 12 is a result of these calculations. The results show a high degree of stability over the test period. The standard deviation of the group was 27.47 feet. No erroneous distance measurements were recorded due to reflections or any other abnormalities during the test.

CONCLUSIONS

Based on these tests, it was concluded that:

1. The data collected during static and flight tests provided an adequate data base for measuring system accuracy.

2. Static test measurements of mean error for the system exceeded 100 feet with a 1-sigma standard deviation of as much as ±50 feet.

3. The flight test data showed mean errors from 10 feet to more than 200 feet, with standard deviation of as much as 20 feet. However, if mean errors were removed, the standard deviation for one sigma error, 0 to 5 nmi, would be ±3 feet during radials and ±9 feet during approaches.

4. The static data showed variations of as much as 79 feet when the airborne interrogator was in the precision mode.

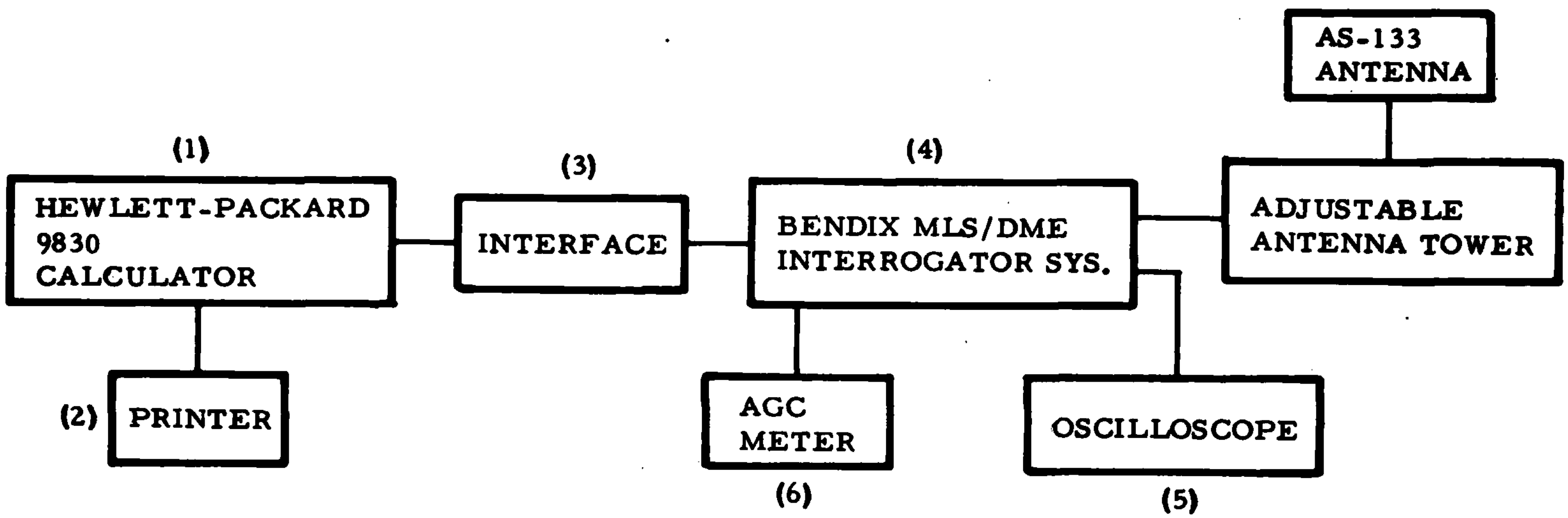
RECOMMENDATIONS

1. Further testing be conducted to determine the effects on system accuracy during ident times.

2. Testing be continued to determine the reasons for shifts in bias.

3. Action be initiated to obtain or modify existing simulators to perform as a test set for Precision Distance Measuring Equipment (PDME).

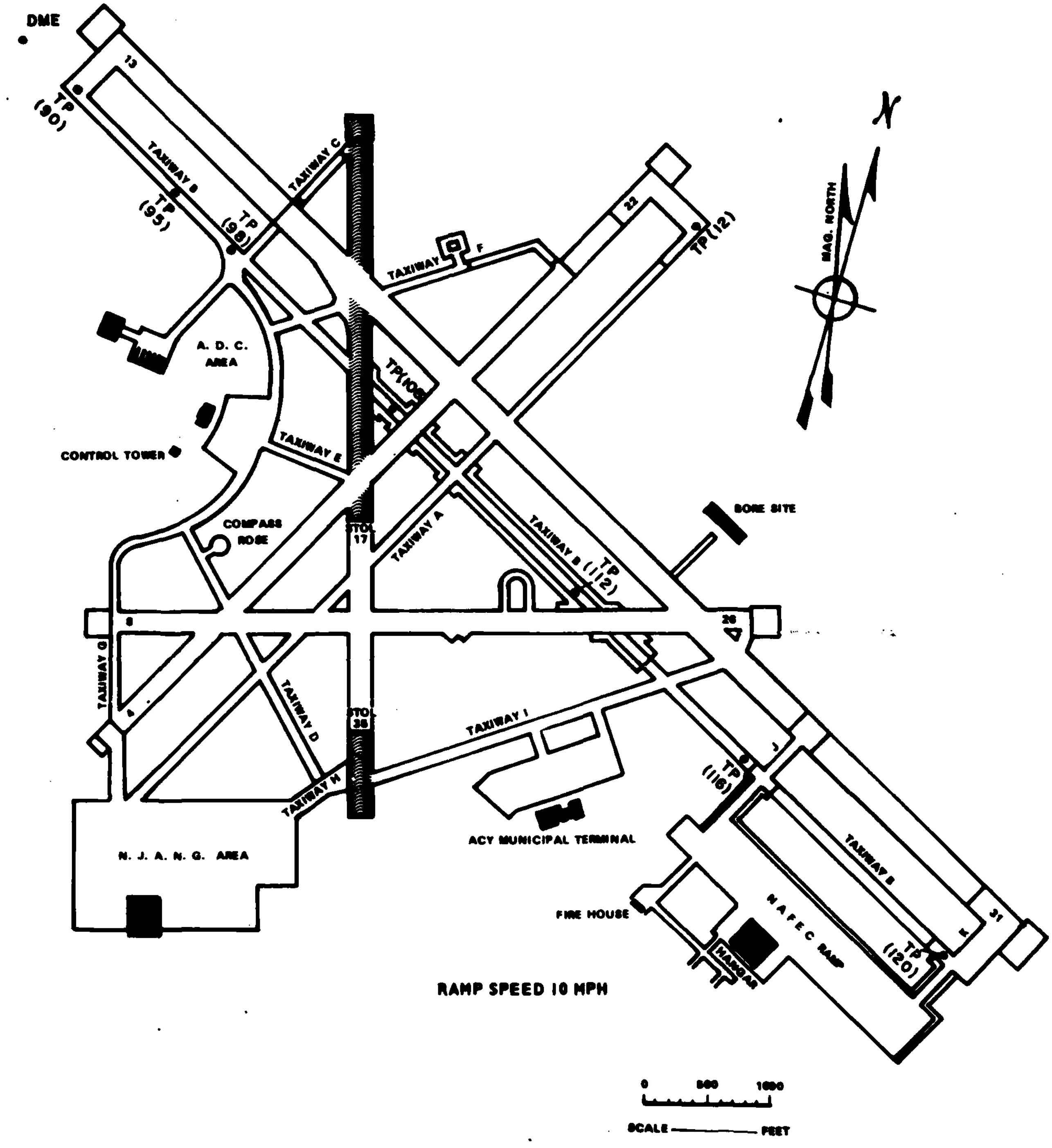
This project was accomplished under Technical Program Document (TPD) 04-309, subprogram 075-725-810. For further information, contact Harold Postel, ACT-100B.1, or Edward M. Sawtelle, Federal Aviation Administration (FAA) Technical Center Program Manager, ACT-100B.1, telephone FTS 8-346-3913, commercial (609) 641-8200, extension 3913.



1. HEWLETT-PACKARD 9830 CALCULATOR
2. HEWLETT-PACKARD 9866 PRINTER
3. LABORATORY INTERFACE
4. MLS/DME PRECISION INTERROGATOR SYSTEM
5. HEWLETT-PACKARD 1741 OSCILLOSCOPE
6. HEWLETT-PACKARD 5328 COUNTER

80-25-1

FIGURE 1. TEST VAN INSTRUMENTATION

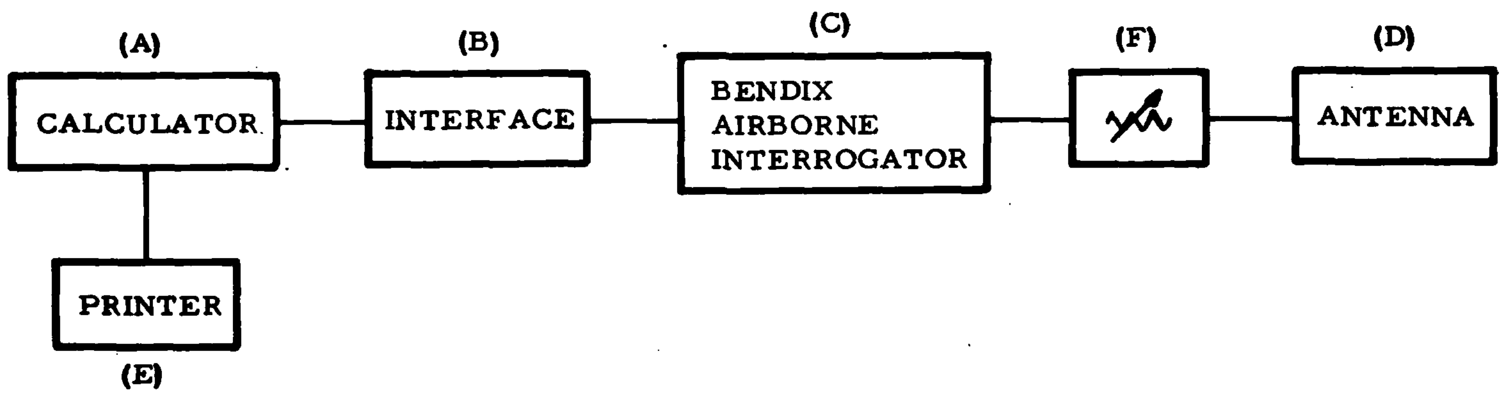


NAFEC/ATLANTIC CITY AIRPORT, ATLANTIC CITY, NEW JERSEY

NA FORM 5320-1 (6-69)

80-25-2

FIGURE 2. TAXIWAY TEST POINTS



A. HEWLETT-PACKARD 9830 DESKTOP COMPUTER
B. LOCALLY FABRICATED INTERFACE ANALOG TO DIGITAL CONVERSION
C. MLS/DME PRECISION SYSTEM, 2041118-1101
D. HORN ANTENNA L-BAND
E. HEWLETT-PACKARD THERMAL PRINTER
F. VARIABLE ATTENUATOR

80-25-4

FIGURE 3. STABILITY TEST INSTRUMENTATION

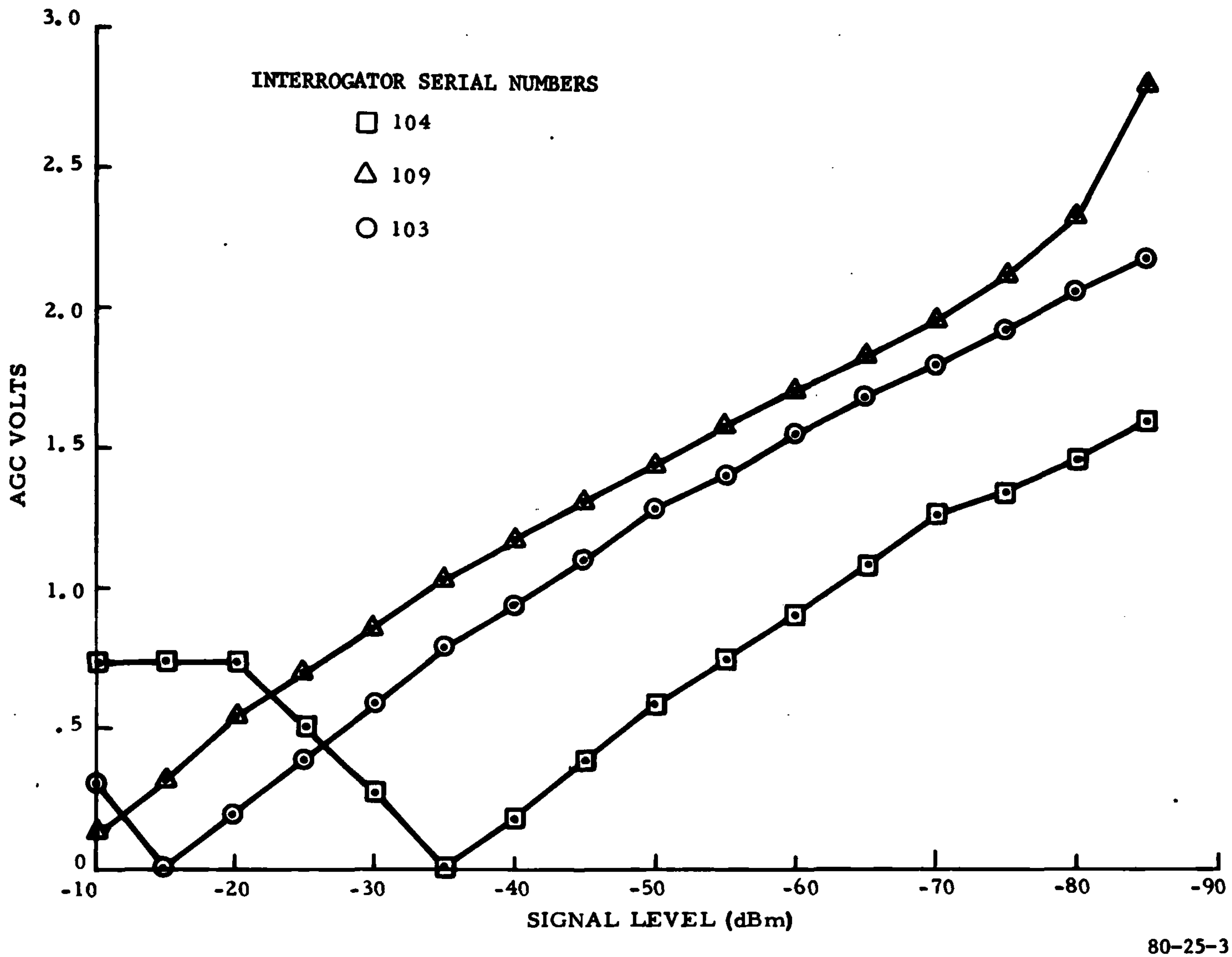


FIGURE 4. SIGNAL LEVEL VERSUS AGC VOLTAGE

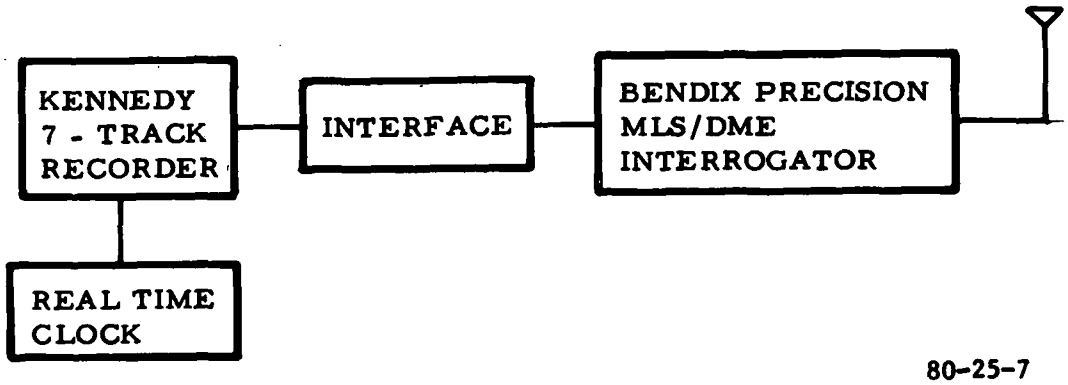


FIGURE 5. AIRBORNE INSTRUMENTATION PACKAGE

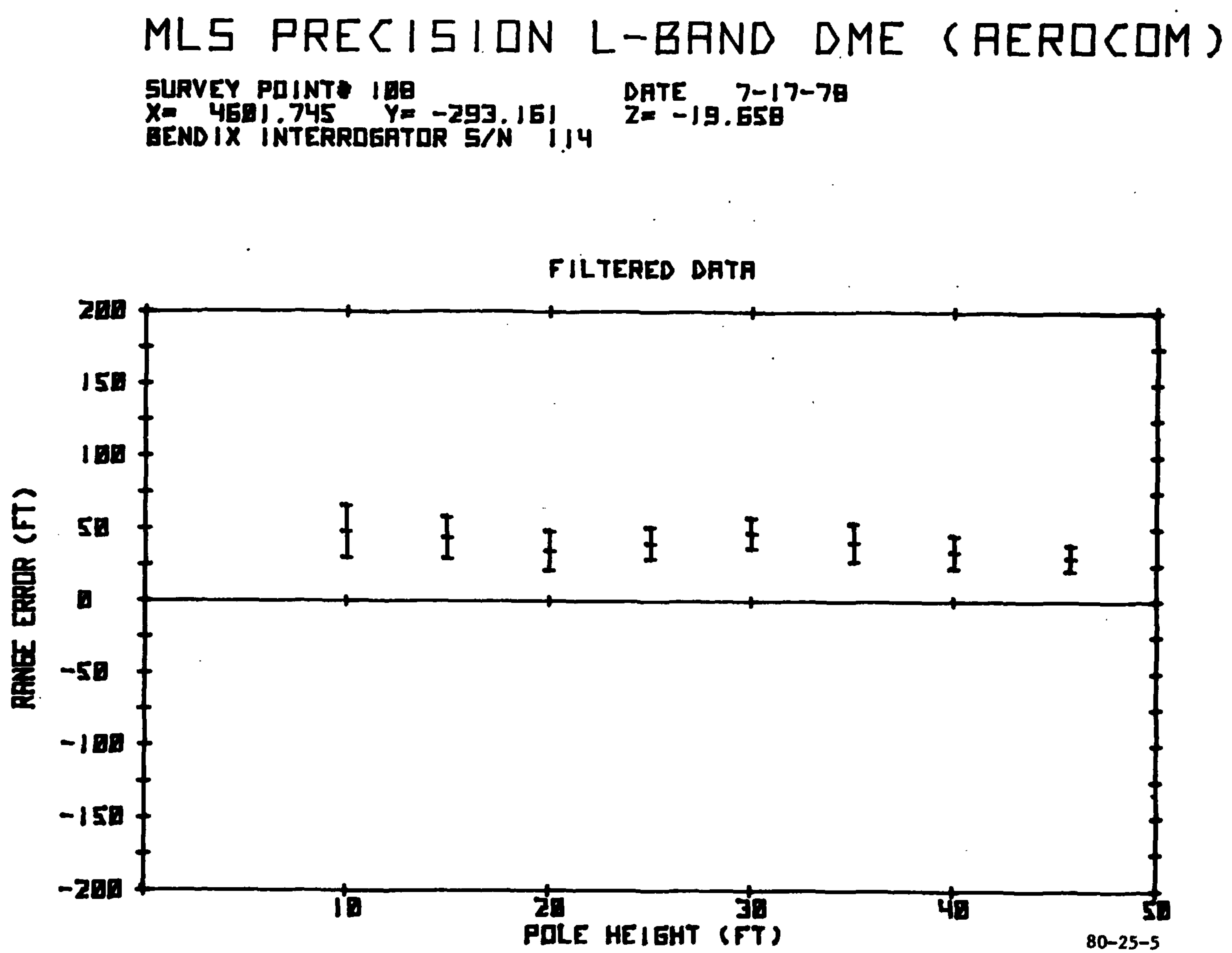


FIGURE 6. VAN DATA PLOTS (SHEET 1 OF 2)

MLS PRECISION L-BAND DME (AERODCOM)

SURVEY POINT# 90 DATE 7-12-78
X= 1001.745 Y= -293.161 Z= -12.190
BENDIX INTERROGATOR S/N 114

FILTERED DATA

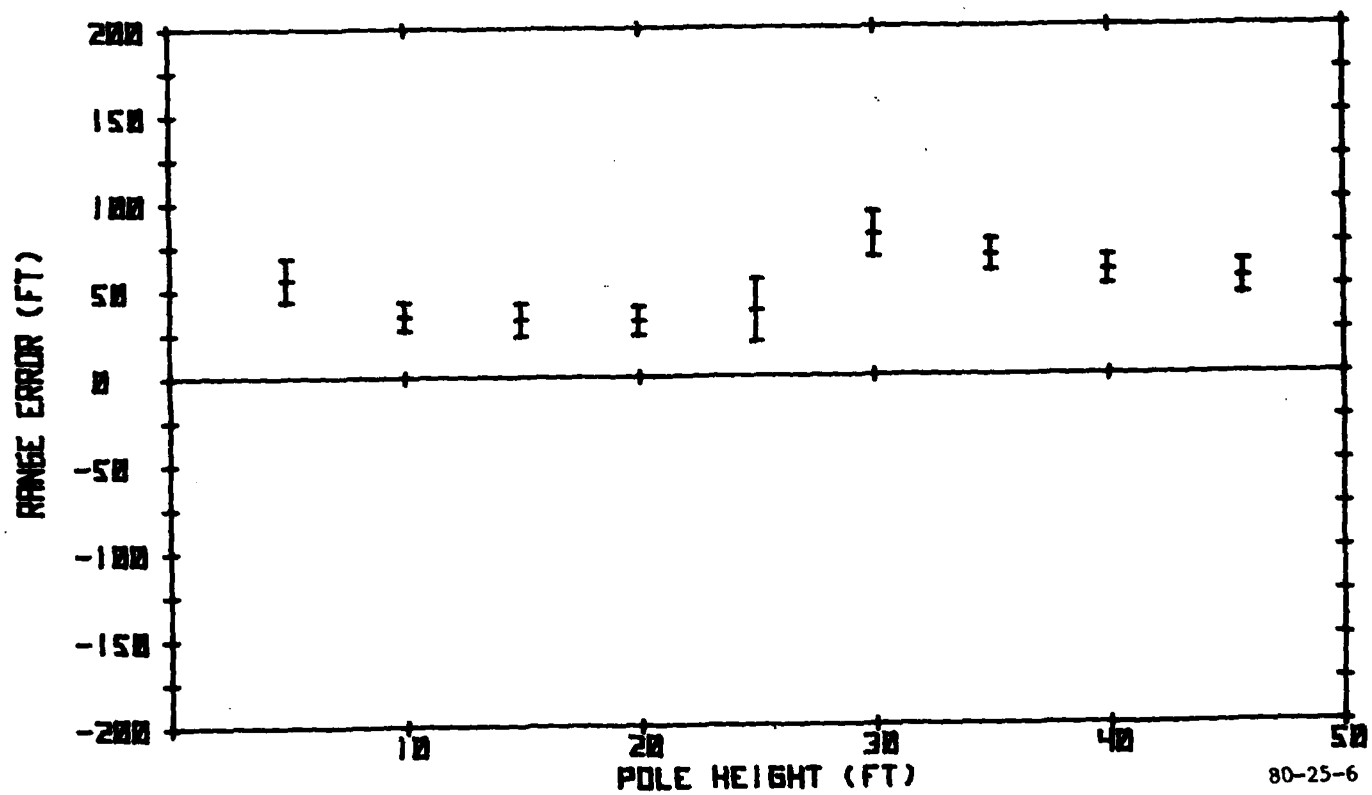


FIGURE 6. VAN DATA PLOTS (SHEET 2 OF 2)

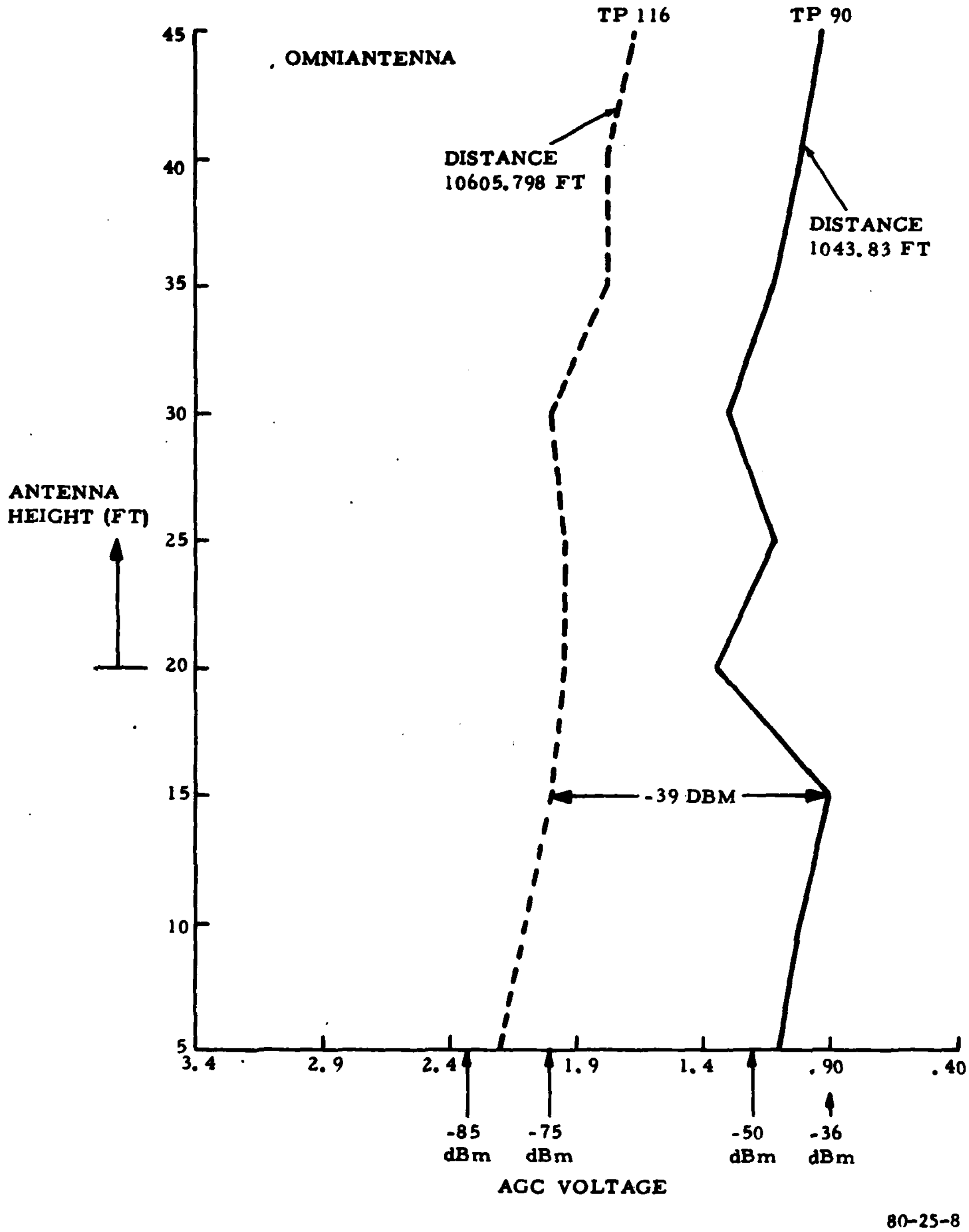
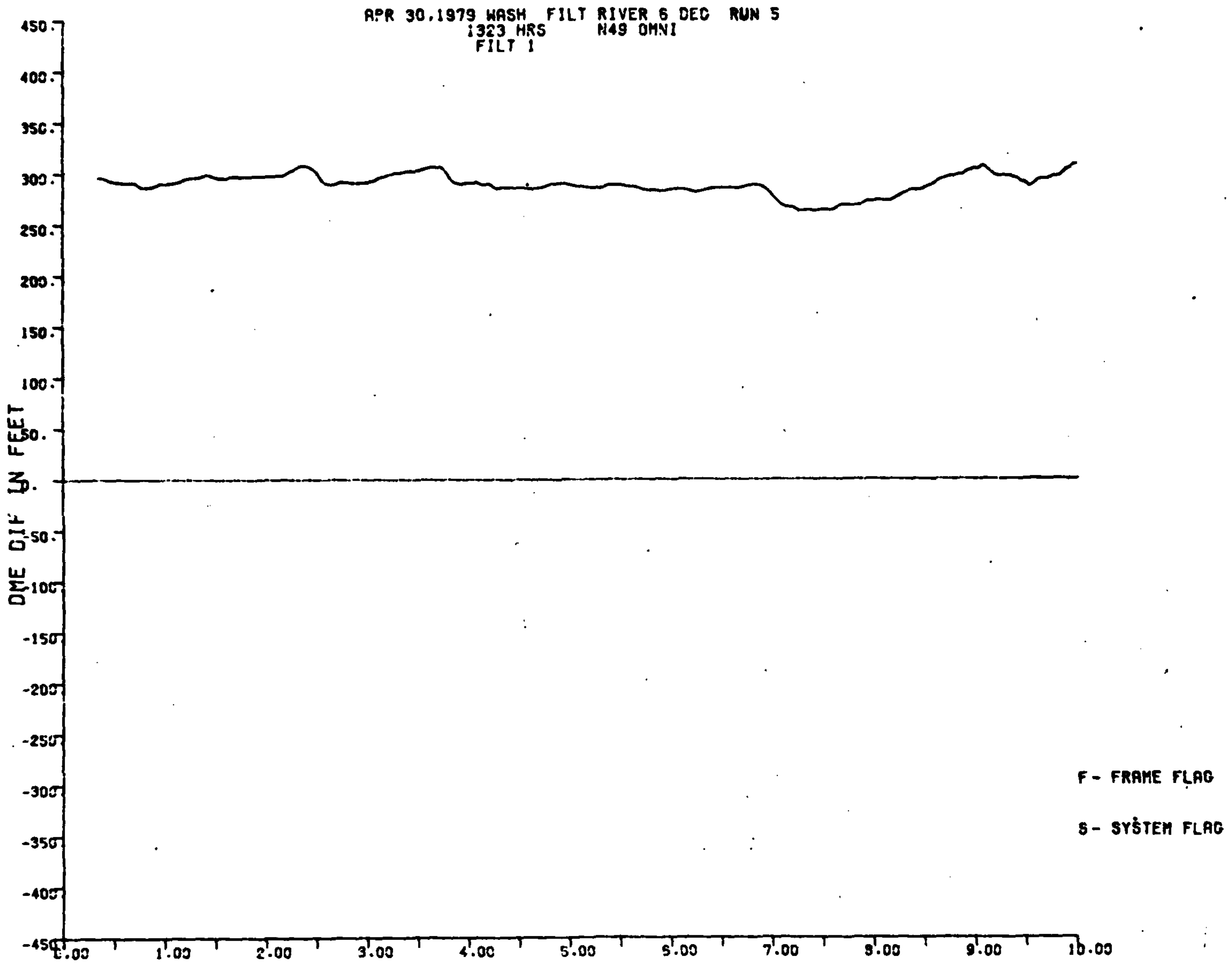


FIGURE 7. PLOT OF ANTENNA HEIGHT VERSUS SIGNAL STRENGTH, BENDIX INTERROGATOR SN-104



80-25-9

FIGURE 8. PLOTS OF FLIGHT DATA (SHEET 1 OF 4)

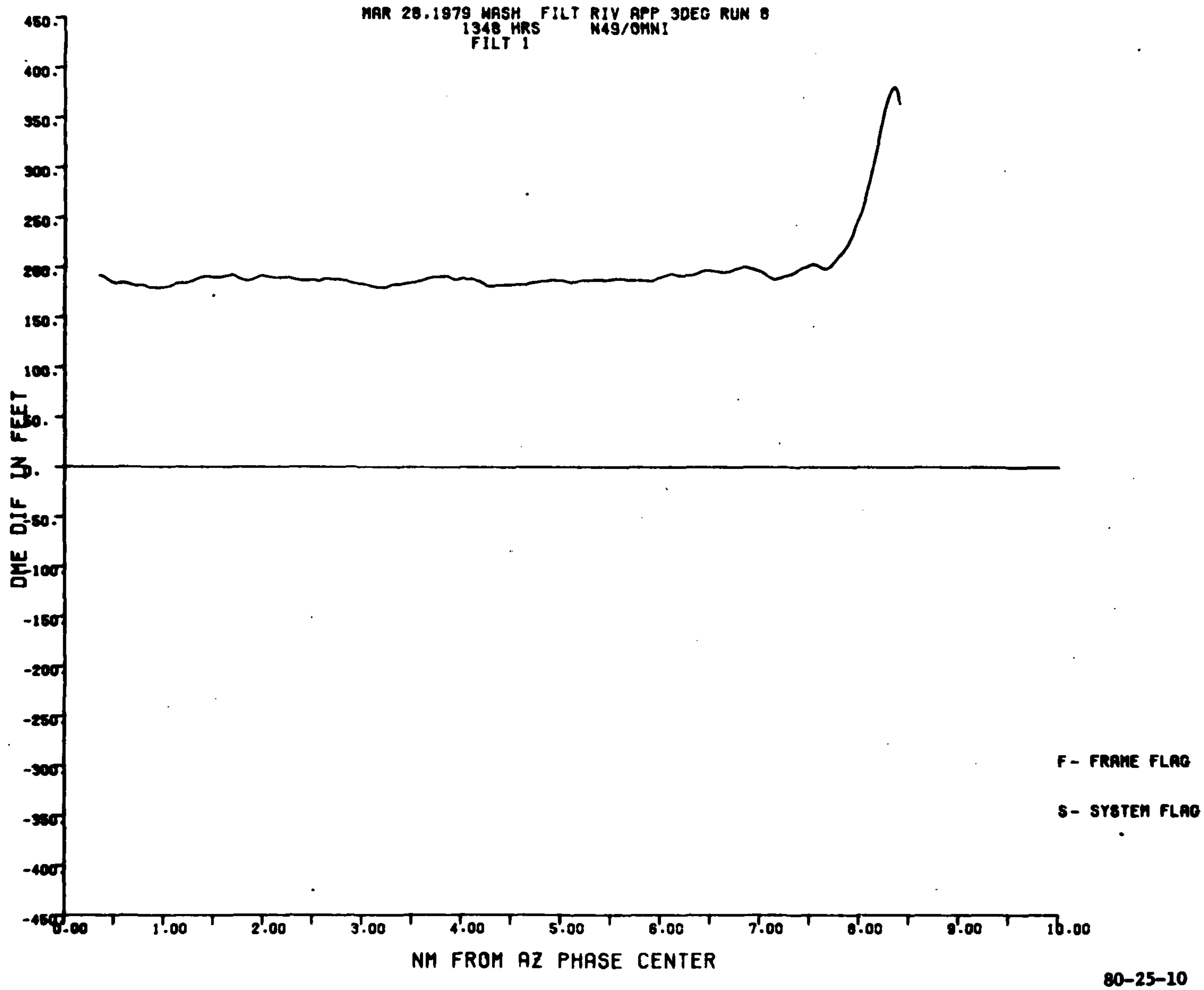
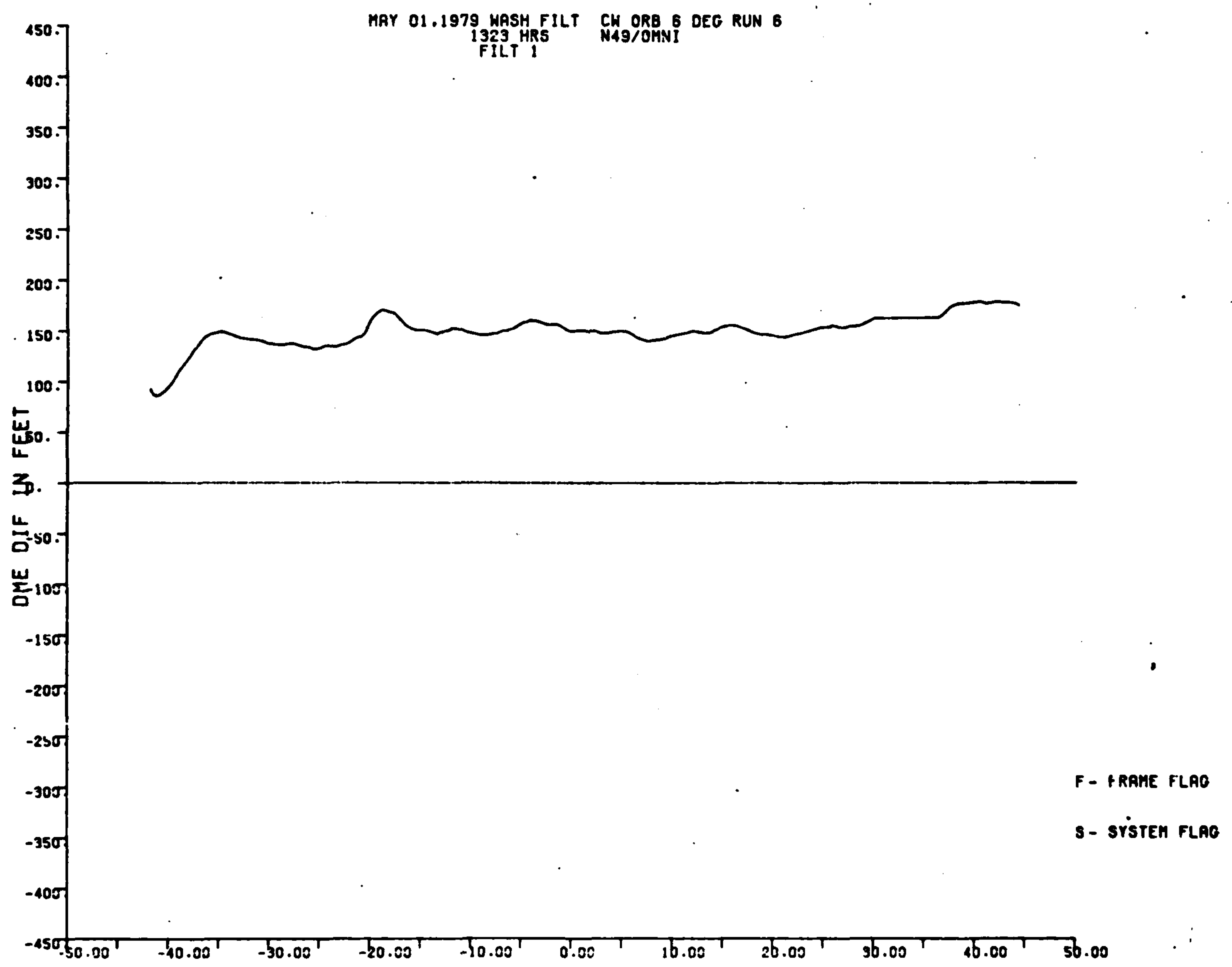
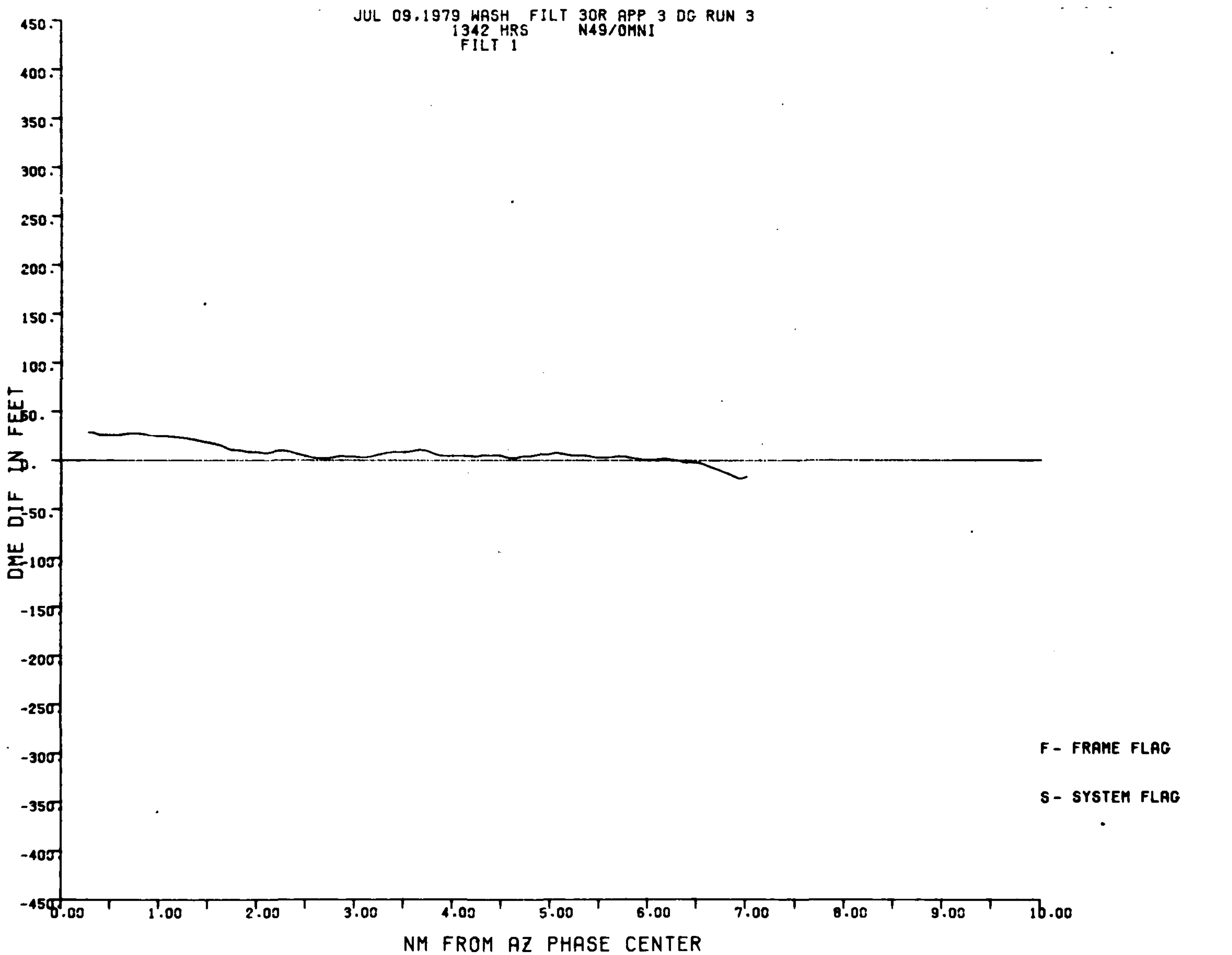


FIGURE 8. PLOTS OF FLIGHT DATA (SHEET 2 OF 4)



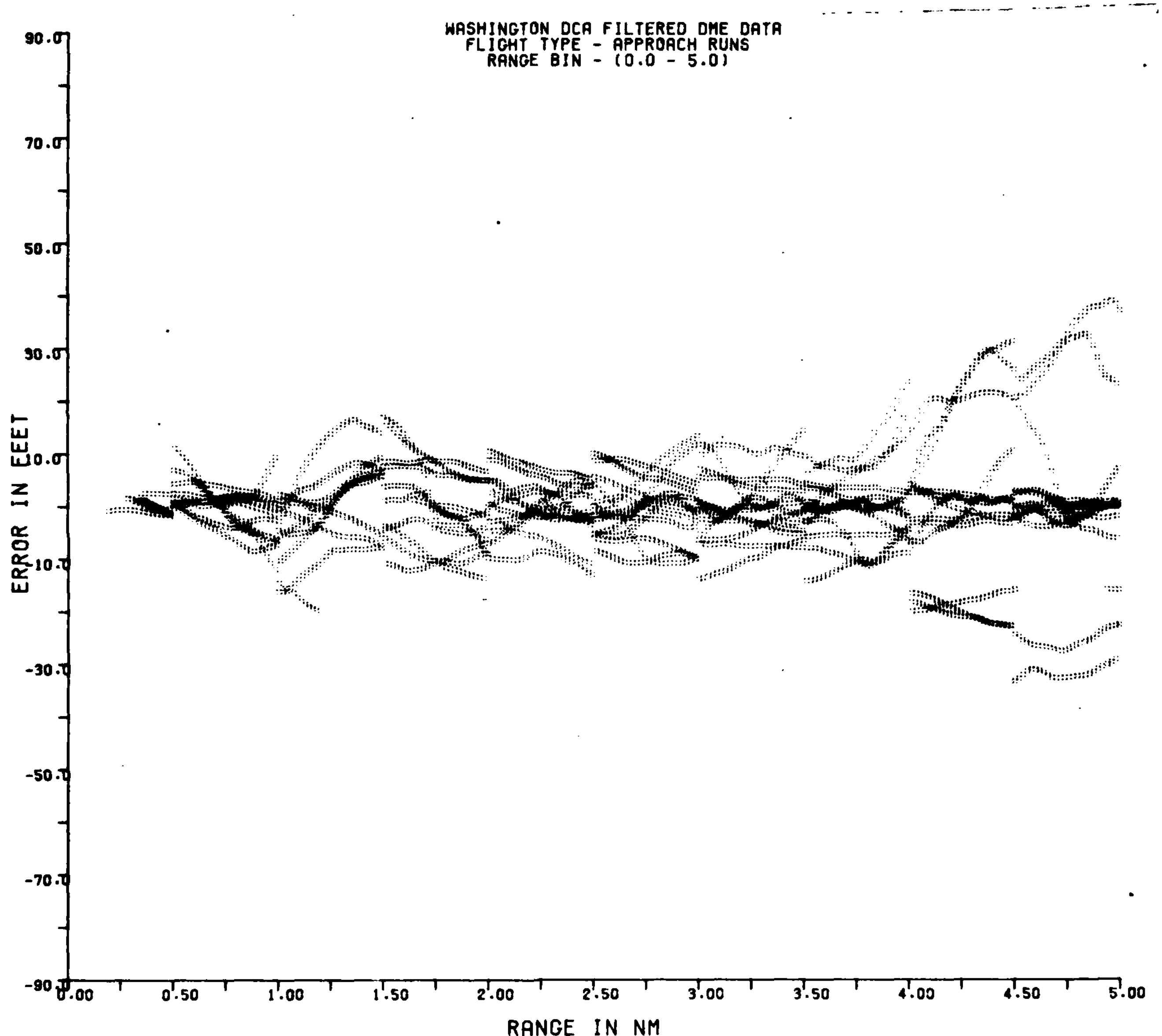
80-25-11

FIGURE 8. PLOTS OF FLIGHT DATA (SHEET 3 OF 4)



80-25-12

FIGURE 8. PLOTS OF FLIGHT DATA (SHEET 4 OF 4)



80-25-13

FIGURE 9. PLOTS OF FLIGHT SCATTER DATA (SHEET 1 OF 6)

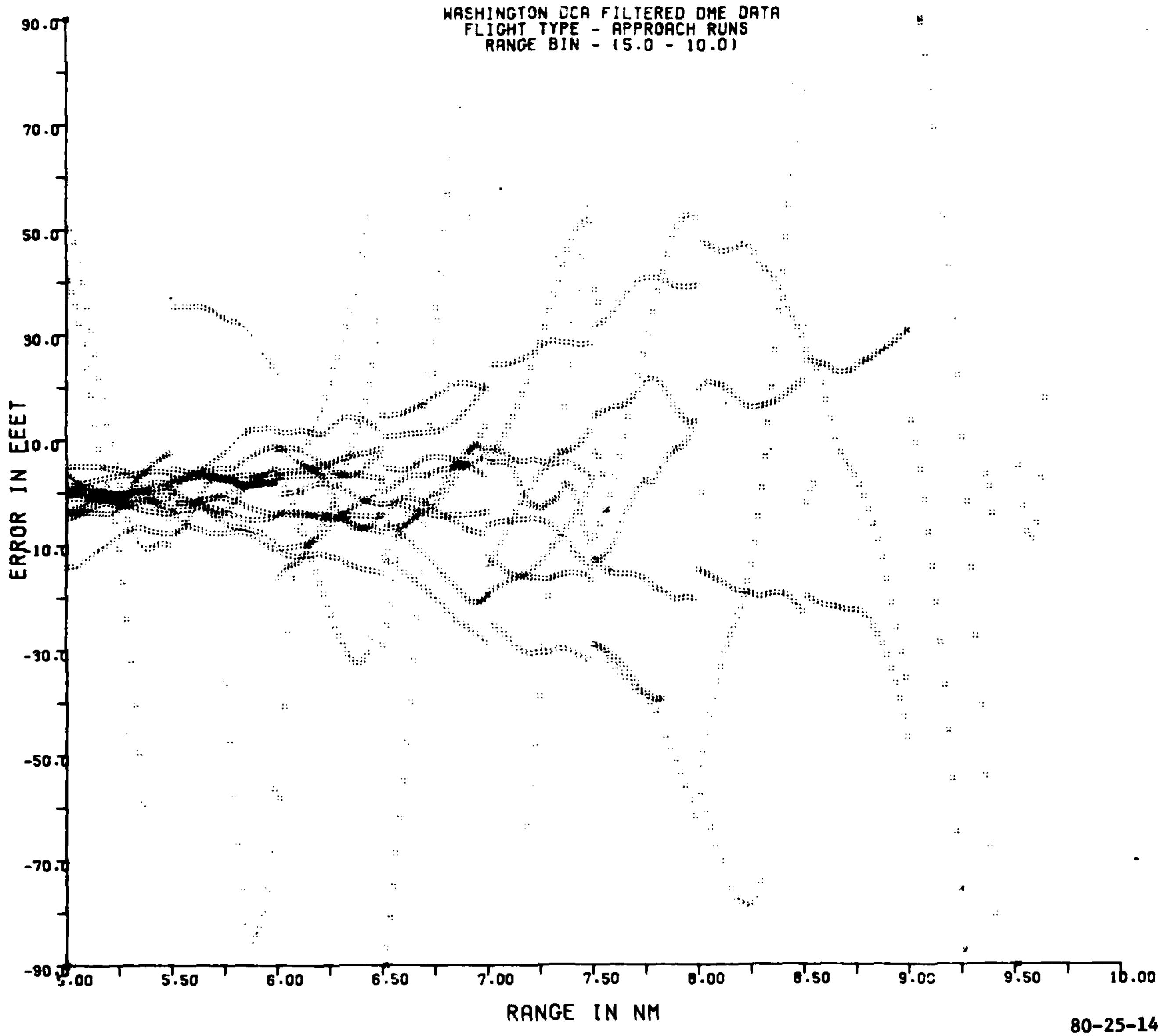
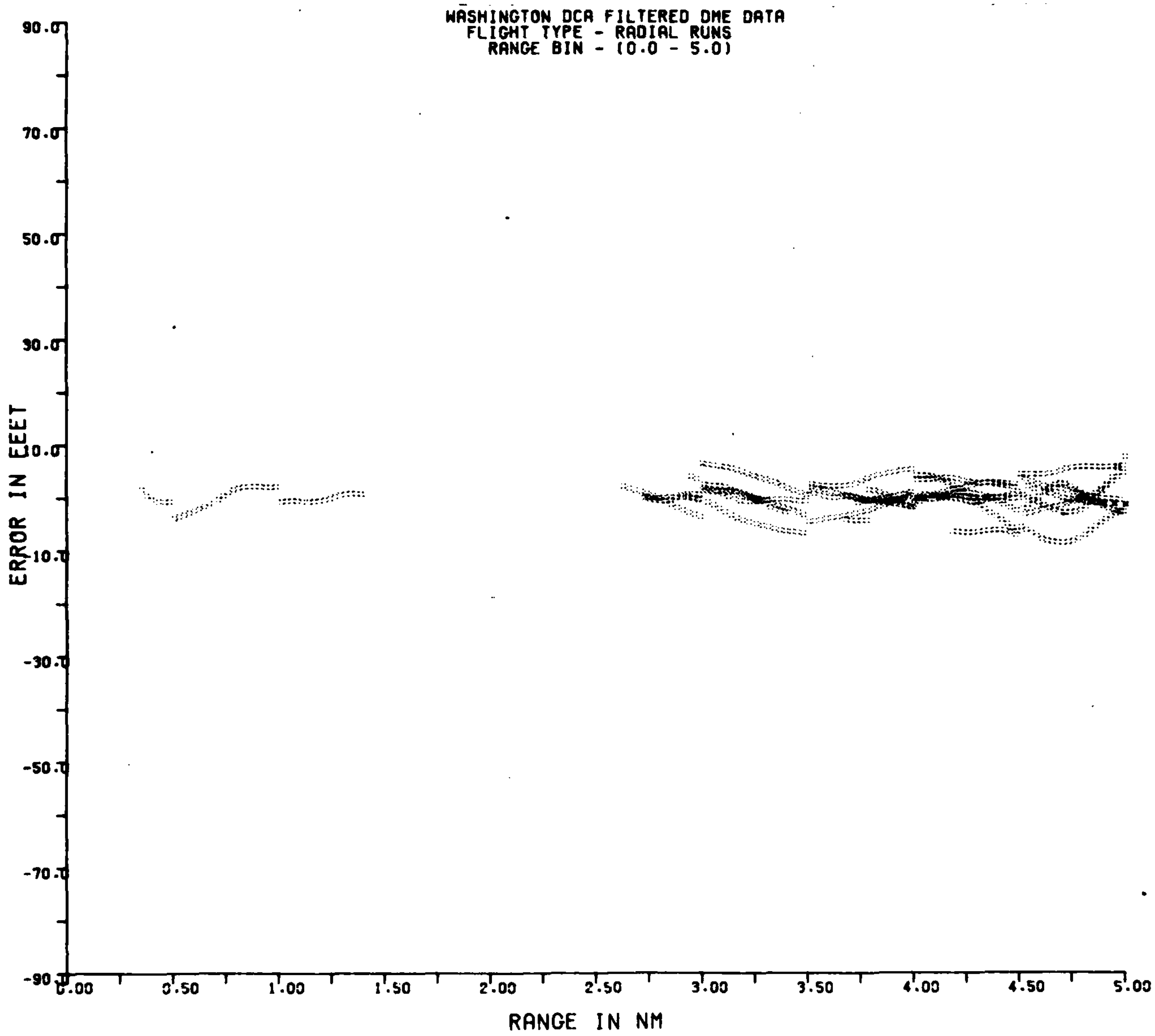


FIGURE 9. PLOTS OF FLIGHT SCATTER DATA (SHEET 2 OF 6)



80-25-15

FIGURE 9. PLOTS OF FLIGHT SCATTER DATA (SHEET 3 OF 6)

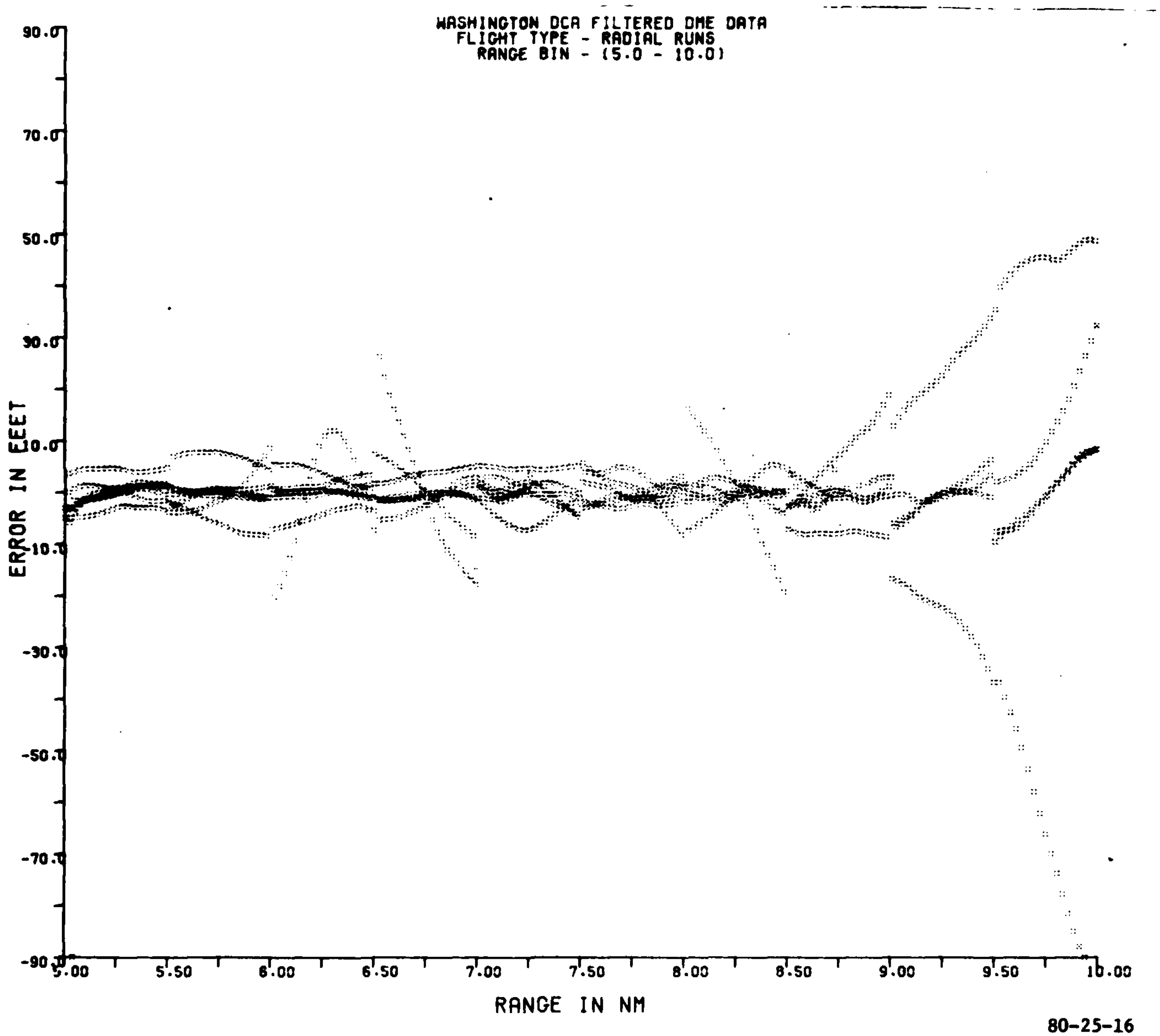
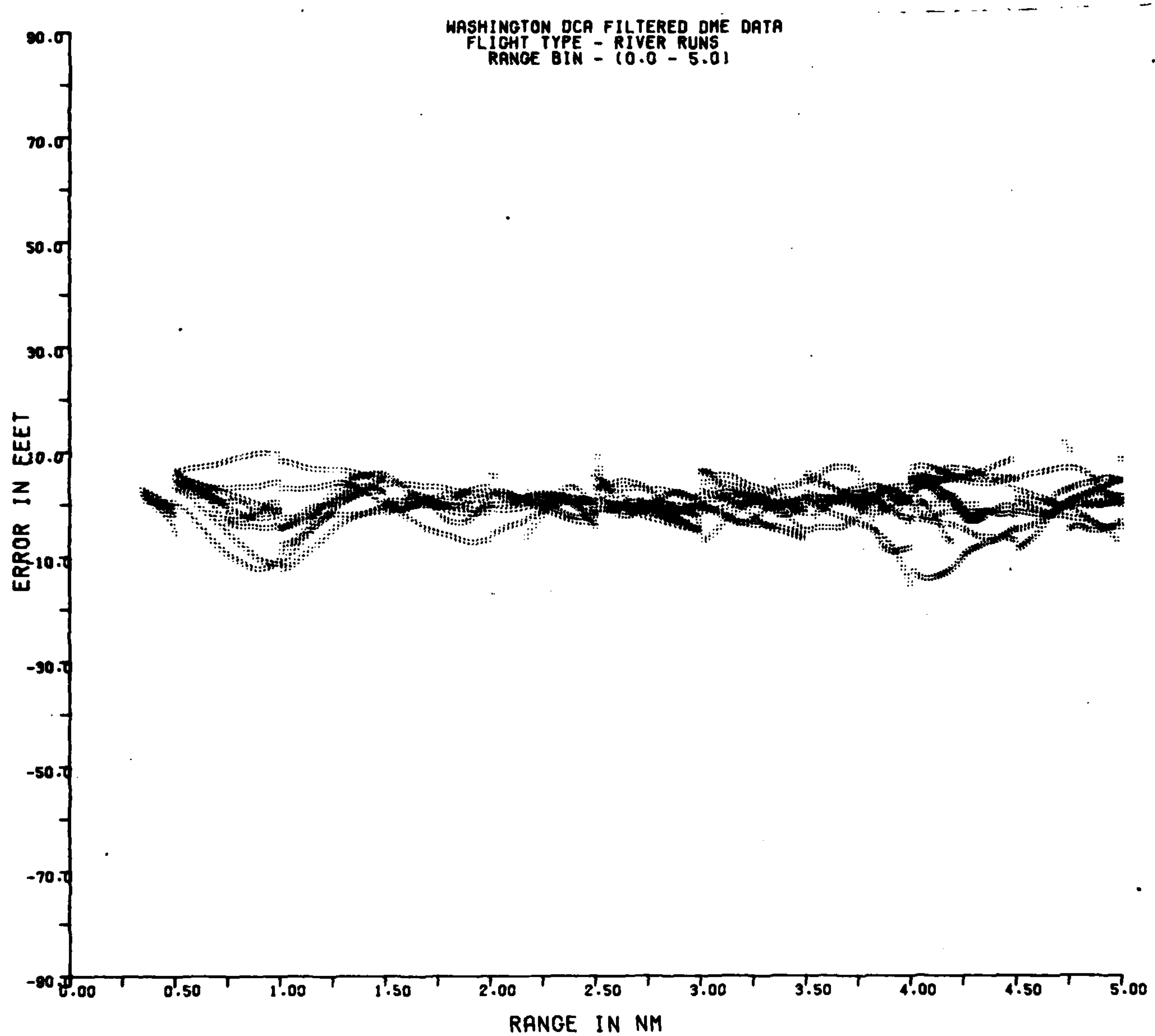


FIGURE 9. PLOTS OF FLIGHT SCATTER DATA (SHEET 4 OF 6)



80-25-17

FIGURE 9. PLOTS OF FLIGHT SCATTER DATA (SHEET 5 OF 6)

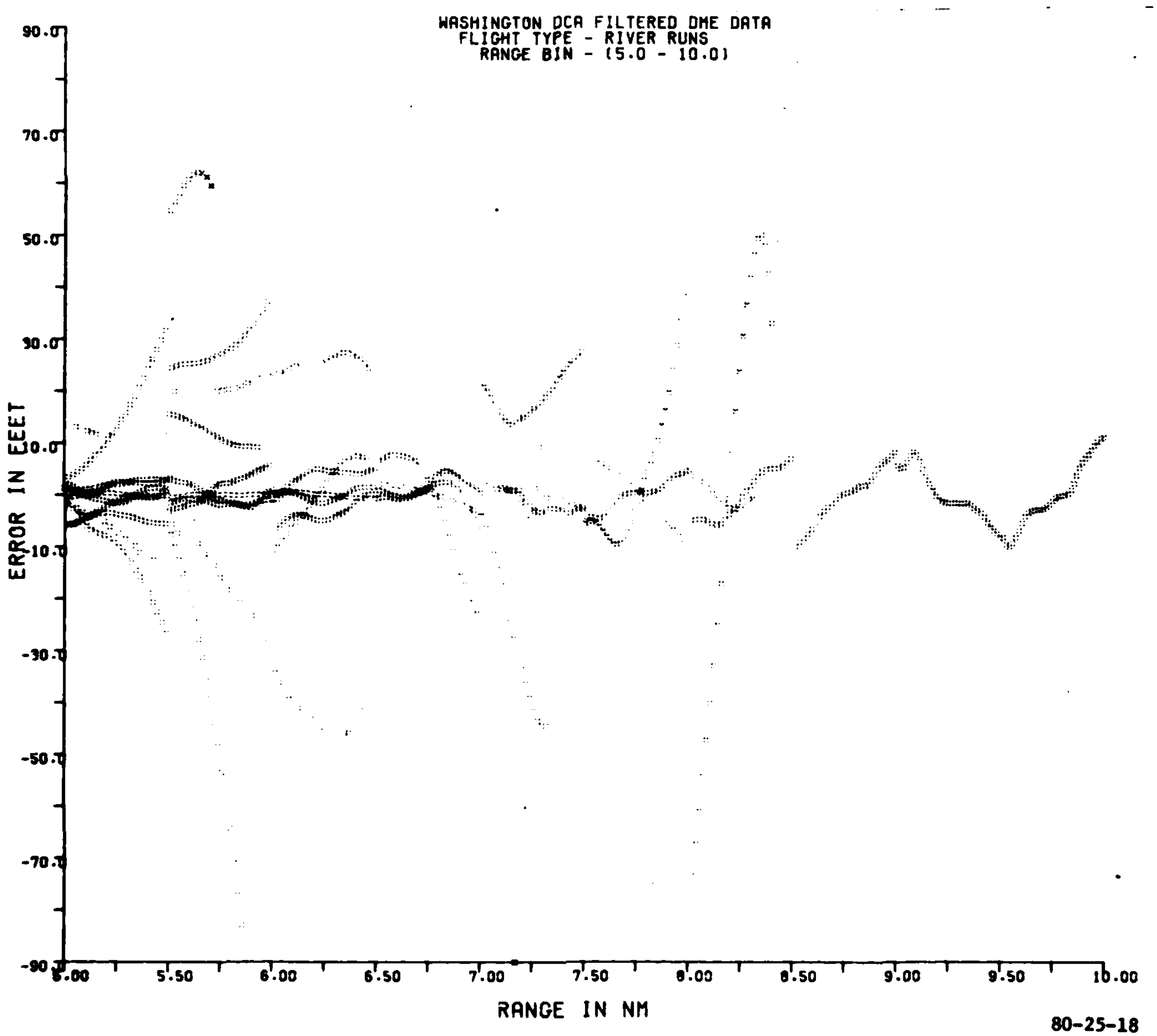


FIGURE 9. PLOTS OF FLIGHT SCATTER DATA (SHEET 6 OF 6)

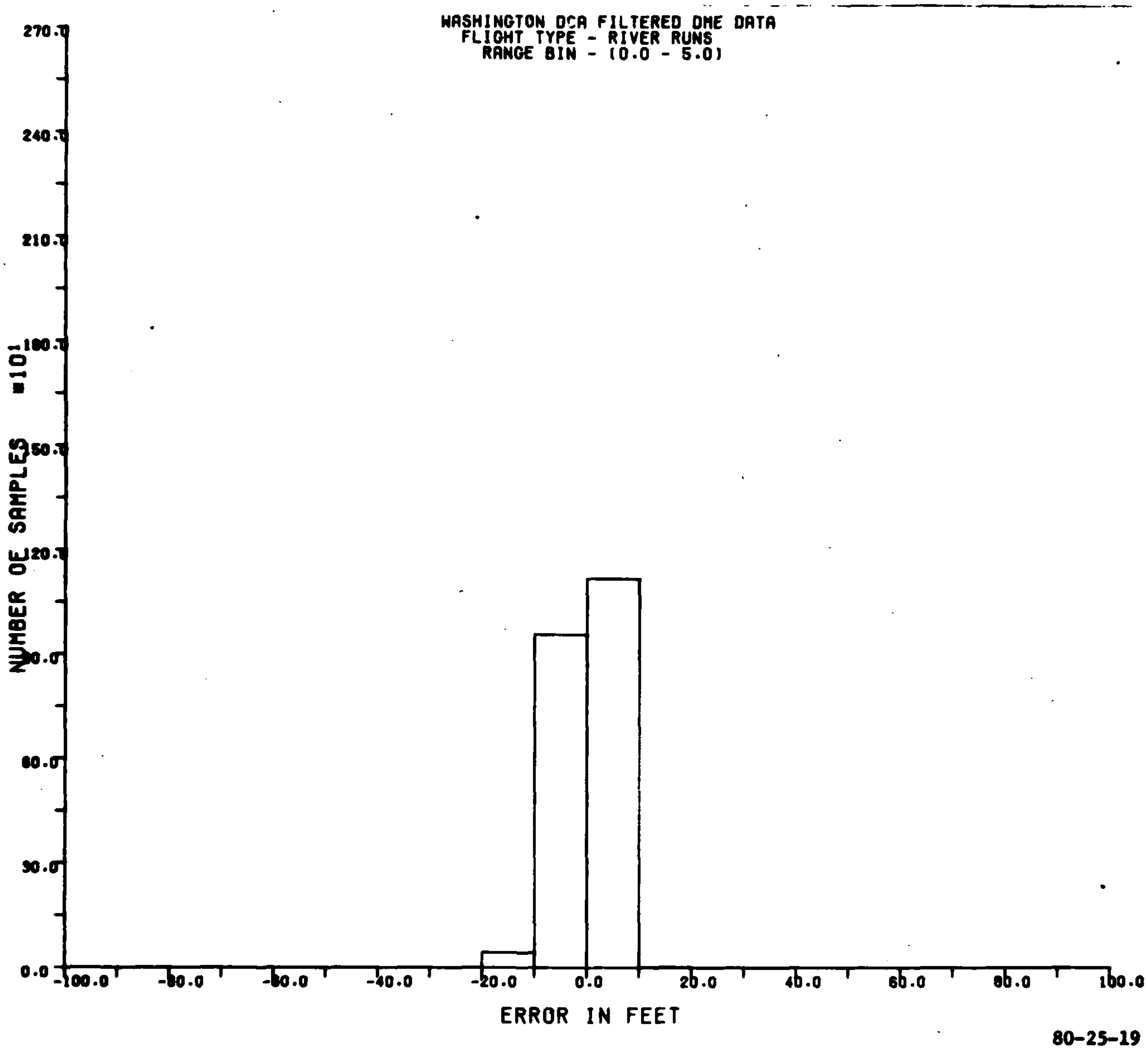


FIGURE 10. HISTOGRAM OF FLIGHTS (SHEET 1 OF 7)

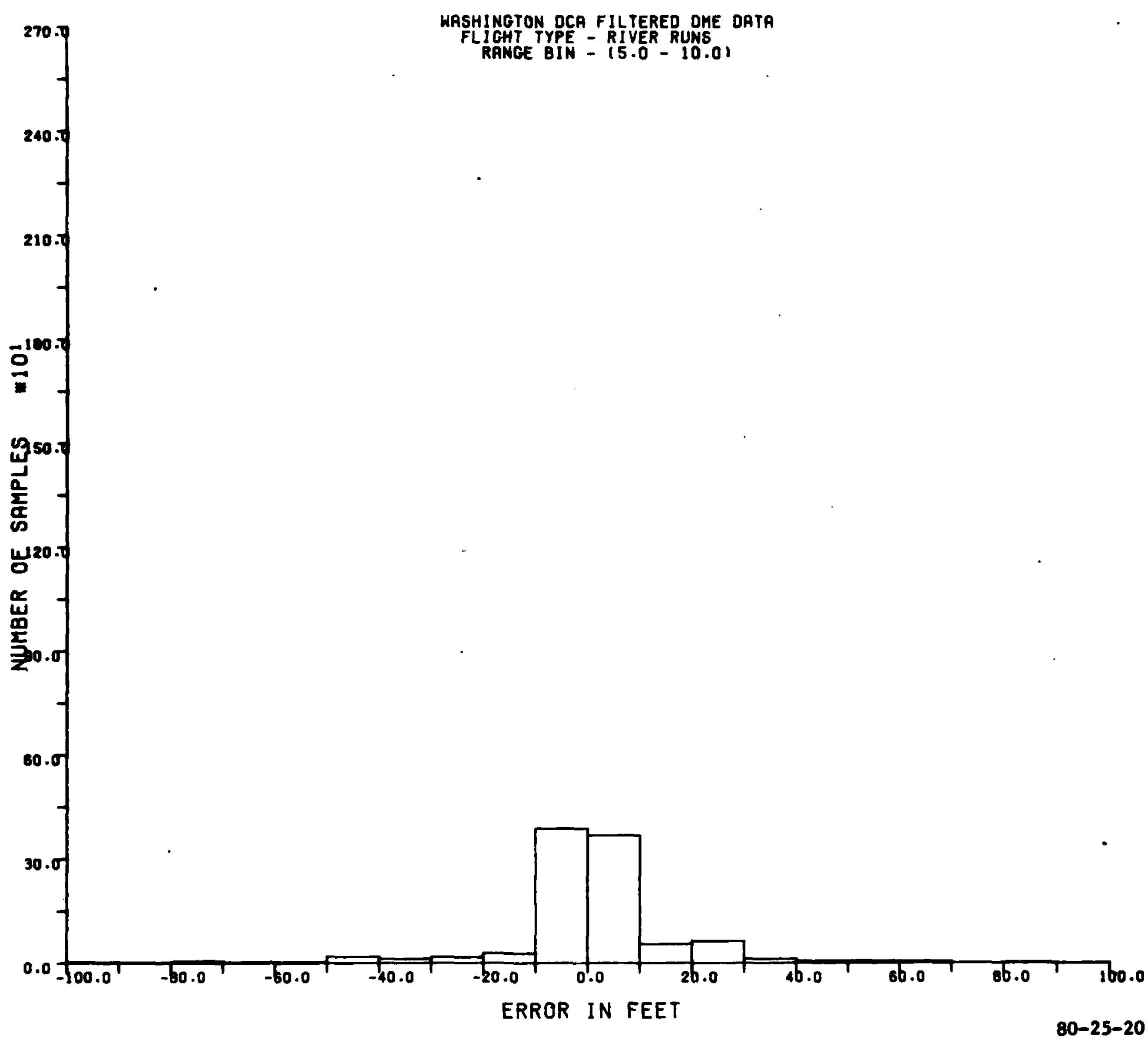
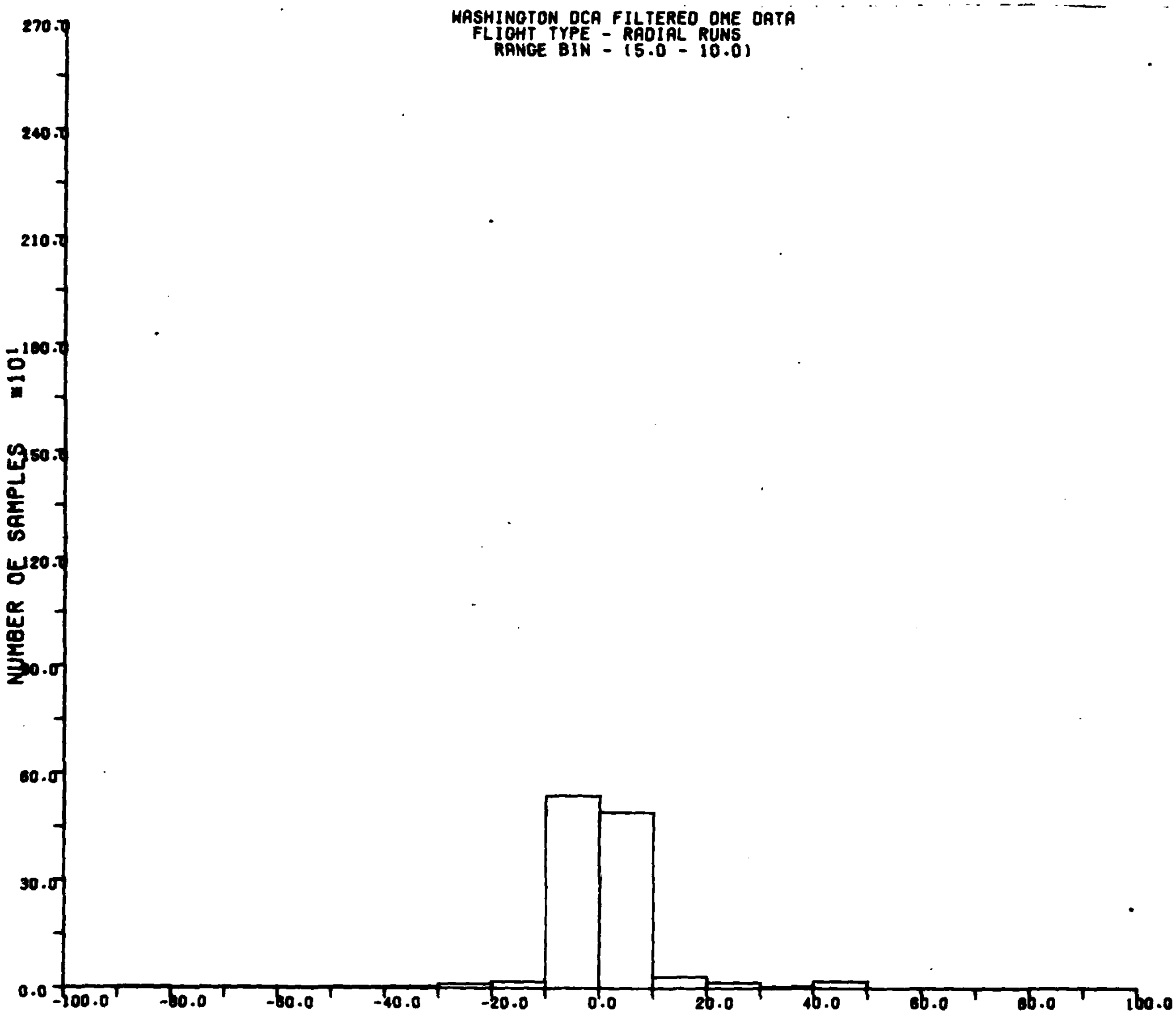
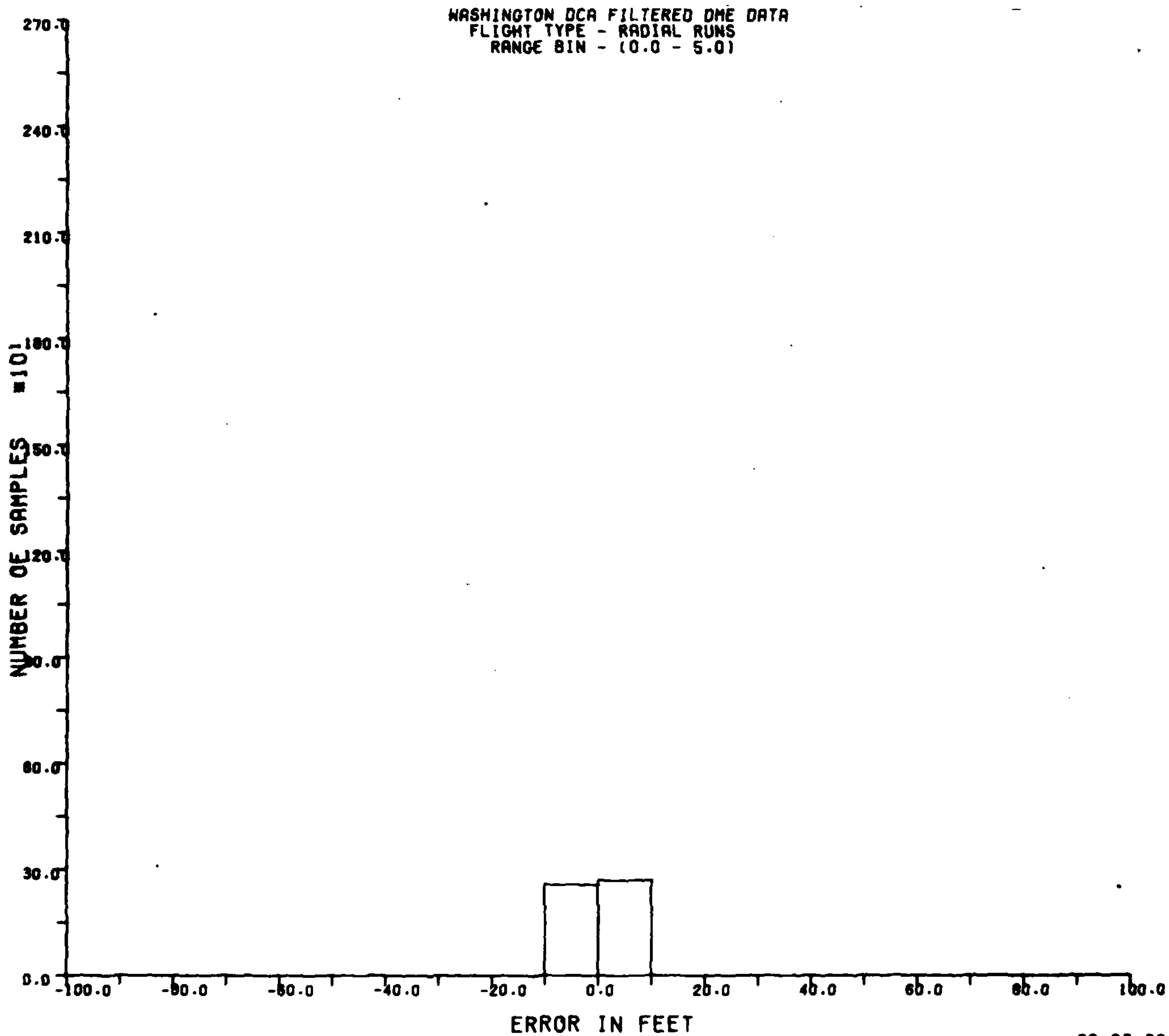


FIGURE 10. HISTOGRAM OF FLIGHTS (SHEET 2 OF 7)



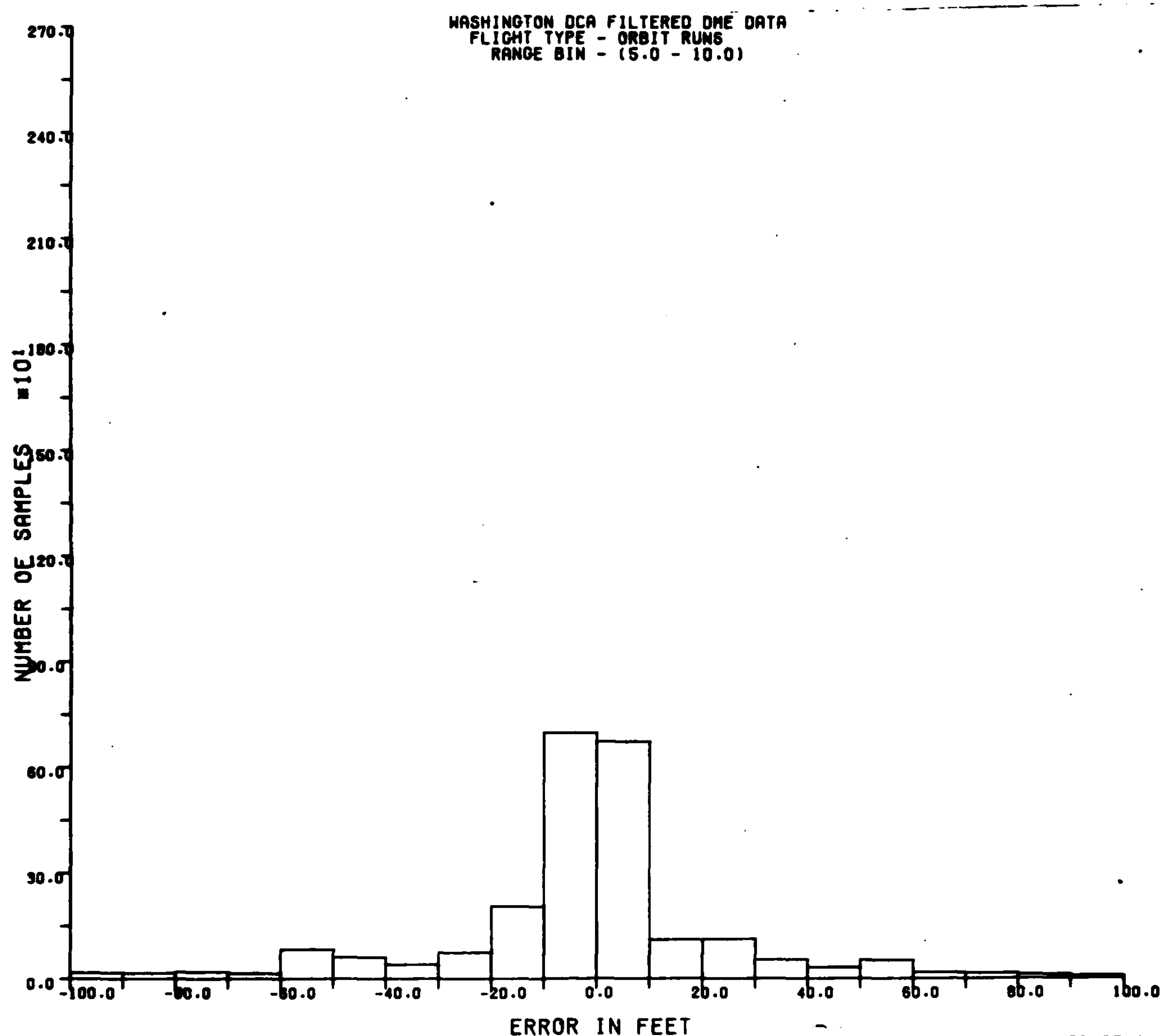
80-25-21

FIGURE 10. HISTOGRAM OF FLIGHTS (SHEET 3 OF 7)



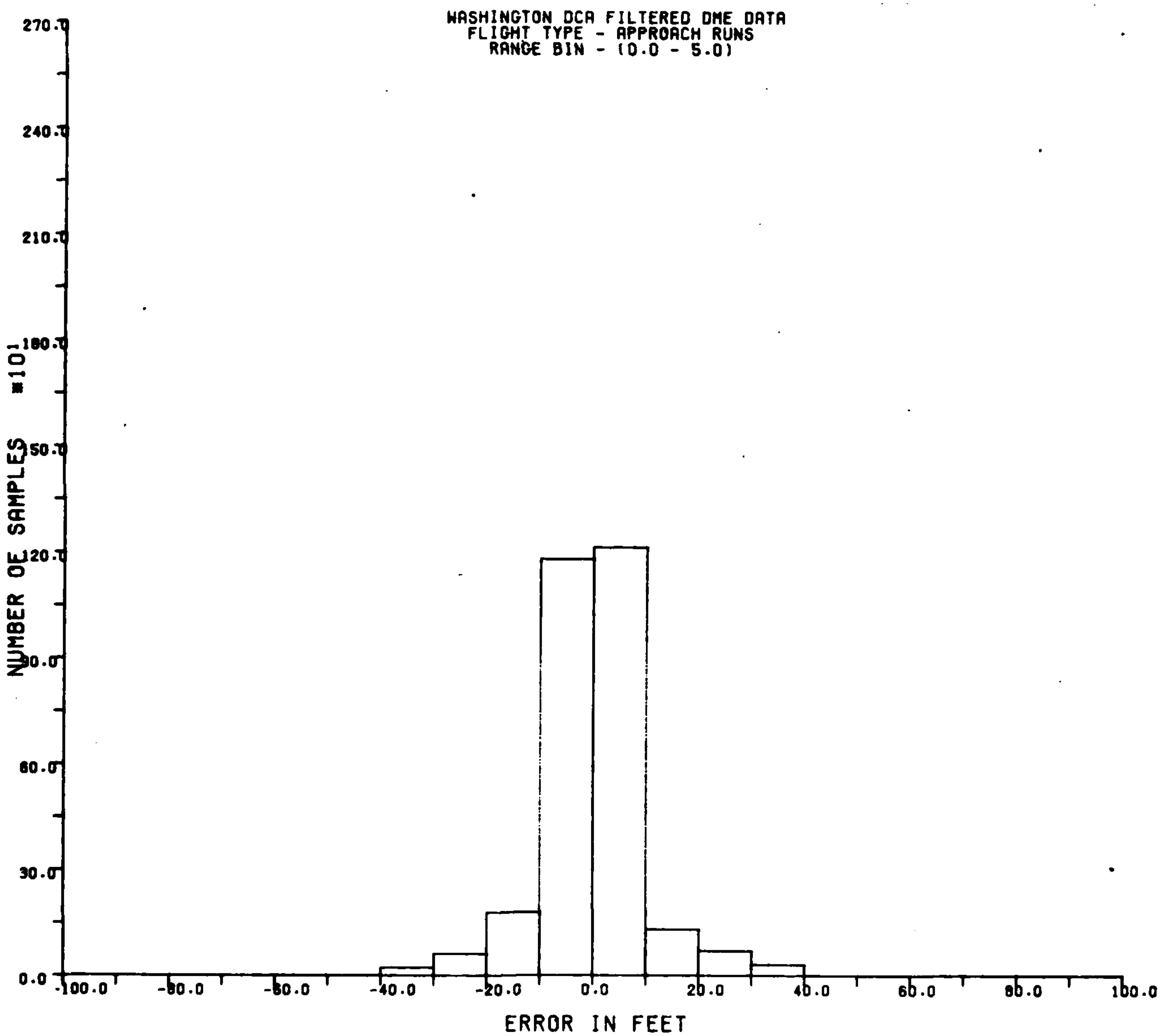
80-25-22

FIGURE 10. HISTOGRAM OF FLIGHTS (SHEET 4 OF 7)



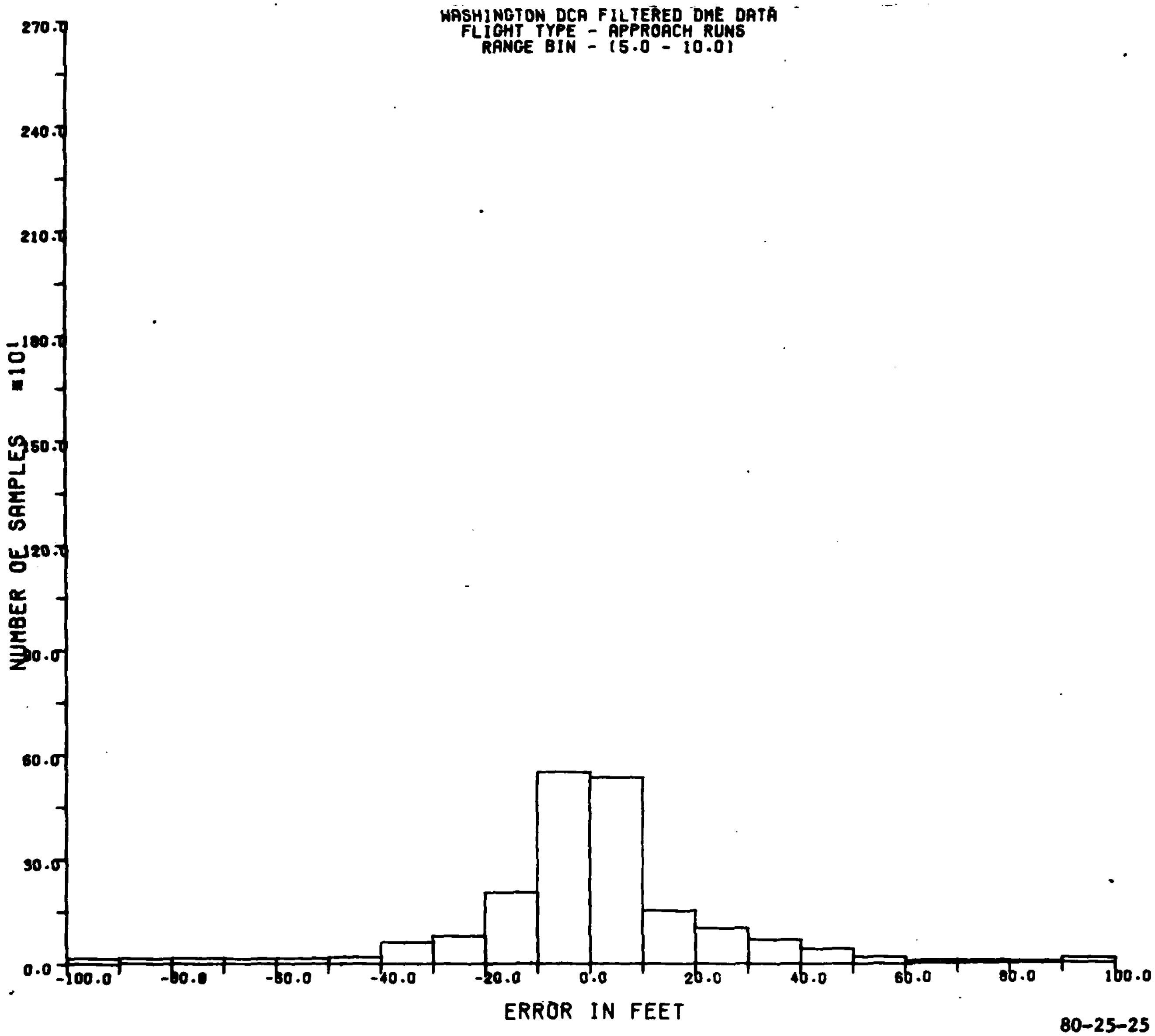
80-25-23

FIGURE 10. HISTOGRAM OF FLIGHTS (SHEET 5 OF 7)



80-25-24

FIGURE 10. HISTOGRAM OF FLIGHTS (SHEET 6 OF 7)



80-25-25

FIGURE 10. HISTOGRAM OF FLIGHTS (SHEET 7 OF 7)

PRECISION DME STABILITY TEST
DATE OF TEST 11/15/78
TYPE - AEROCOM
RANGE - 9559.823708

		MEAN OF DIFF	STAND DEV
SAMPLE	1	501.20627730	27.92836452
SAMPLE	2	494.60206840	24.85668795
SAMPLE	3	495.14230240	23.19867858
SAMPLE	4	506.99103020	23.89018329
SAMPLE	5	512.02309740	24.92077967
SAMPLE	6	505.49779900	25.24851504
SAMPLE	7	503.18511200	26.29222476
SAMPLE	8	506.58433710	24.74976879
SAMPLE	9	513.35243730	24.42382688
SAMPLE	10	517.19477570	24.57177260
SAMPLE	11	517.33439600	24.45273650
SAMPLE	12	487.70649730	22.30284055
SAMPLE	13	480.50135400	21.95294419
SAMPLE	14	508.87691410	24.46335831
SAMPLE	15	507.37344300	24.77697925
SAMPLE	16	508.28394970	24.59330076
SAMPLE	17	515.30092170	24.69526240
SAMPLE	18	520.12053740	25.24528277
SAMPLE	19	519.37392190	25.26297976
SAMPLE	20	517.58932860	25.78321388
SAMPLE	21	509.86323150	24.67546919
SAMPLE	22	514.97313930	24.97225680
SAMPLE	23	512.71508250	24.56640650
SAMPLE	24	511.73173530	26.50628594
SAMPLE	25	512.52084110	24.78753633
SAMPLE	26	512.02916750	26.84336095
SAMPLE	27	513.12177560	25.63448206
SAMPLE	28	510.20208390	26.98326180
SAMPLE	29	511.93204670	23.92634901

80-25-26

FIGURE 11. SAMPLE DATA OF DME STABILITY TESTS (SHEET 1 OF 3)

SAMPLE	30	512.34480980	24.50430920
SAMPLE	31	513.12784560	24.34384536
SAMPLE	32	515.00955950	27.12437281
SAMPLE	33	516.64847170	27.93334699
SAMPLE	34	519.00971920	26.17876458
SAMPLE	35	488.83552570	22.32311458
SAMPLE	36	489.31505920	22.41132255
SAMPLE	37	488.93871650	22.23469707
SAMPLE	38	488.96587590	22.23089692
SAMPLE	39	469.41218000	22.24609115
SAMPLE	40	488.68984460	22.33118676
SAMPLE	41	483.55023360	22.32561580
SAMPLE	42	487.99785950	22.21556408
SAMPLE	43	484.33155230	22.25667706
SAMPLE	44	481.96423480	22.22214379
SAMPLE	45	479.49823510	21.86604585
SAMPLE	46	478.82602160	21.89425871
SAMPLE	47	478.23115720	21.75203664
SAMPLE	48	477.91551480	21.75063889
SAMPLE	49	476.99893800	21.81935602
SAMPLE	30	478.41325850	22.00943839
SAMPLE	51	500.17436970	24.81739184
SAMPLE	52	480.39209320	22.87955238
SAMPLE	53	479.22057450	21.94547219
SAMPLE	54	491.32051000	22.03249620
SAMPLE	55	464.59863430	22.46022927
SAMPLE	56	485.35131999	22.19211396
SAMPLE	57	484.79287580	22.12852579
SAMPLE	58	496.17077600	22.23153310
SAMPLE	59	486.05544510	22.19840125
SAMPLE	60	486.46213810	22.24408293
SAMPLE	61	496.06151510	22.24785997
SAMPLE	62	485.52735120	22.21284204
SAMPLE	63	485.27240930	22.15172042
SAMPLE	64	484.06875050	22.18714144

80-25-27

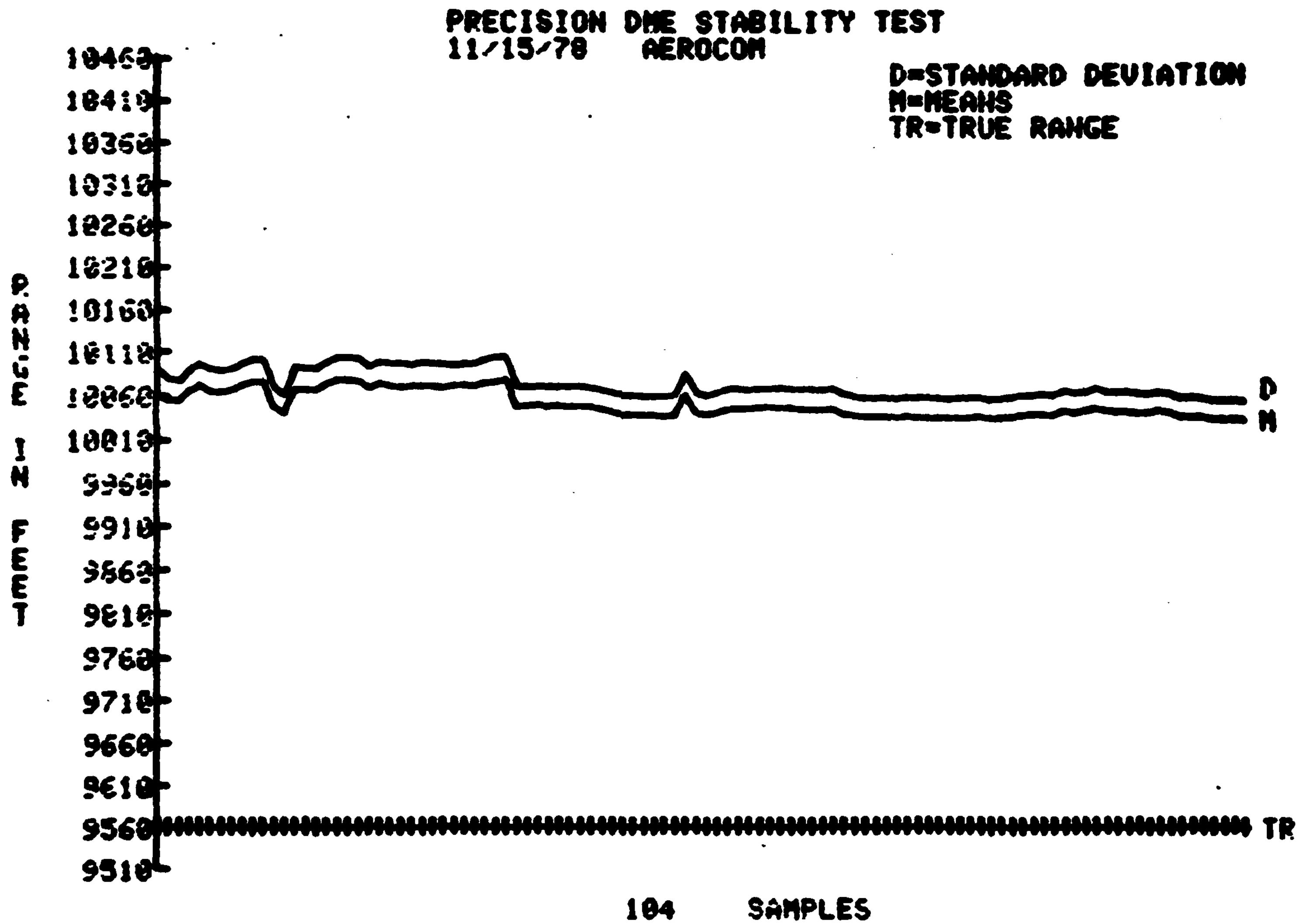
FIGURE 11. SAMPLE DATA OF DME STABILITY TESTS (SHEET 2 OF 3)

SAMPLE	65	485.40595030	22.09143360
SAMPLE	66	479.87006930	22.13646989
SAMPLE	67	478.00049540	22.00574770
SAMPLE	68	476.56189480	21.73414134
SAMPLE	69	476.44656390	21.67807099
SAMPLE	70	476.11878150	21.71072746
SAMPLE	71	475.52998720	21.67984129
SAMPLE	72	476.07629120	21.77420566
SAMPLE	73	475.63924800	21.69283383
SAMPLE	74	475.73636870	21.73684794
SAMPLE	75	475.73636870	21.67726082
SAMPLE	76	475.22648499	21.72693686
SAMPLE	77	475.57854759	21.69815441
SAMPLE	78	475.71815859	21.68694198
SAMPLE	79	476.25839250	21.96909530
SAMPLE	80	474.64983060	21.62593997
SAMPLE	81	475.09901400	21.80551927
SAMPLE	82	476.76220630	21.89415956
SAMPLE	83	478.03691570	22.01981583
SAMPLE	84	479.33590530	22.09863133
SAMPLE	85	480.08859090	22.14259975
SAMPLE	86	478.47395900	21.97740290
SAMPLE	87	483.79738840	22.02953982
SAMPLE	88	481.22975940	22.12803597
SAMPLE	89	483.37248520	22.10930352
SAMPLE	90	487.28143460	21.97541433
SAMPLE	91	483.00328250	21.94525699
SAMPLE	92	482.92330190	22.00328124
SAMPLE	93	482.65046140	21.97445924
SAMPLE	94	481.48470130	22.07888659
SAMPLE	95	480.18571160	22.01948434
SAMPLE	96	483.14789360	21.98954049
SAMPLE	97	482.19882650	21.92185909
SAMPLE	98	476.31302300	21.87101066
SAMPLE	99	477.08391870	21.90579448
SAMPLE	100	476.36158330	21.94475810
SAMPLE	101	473.88500500	21.56759131
SAMPLE	102	473.53901240	21.52305143
SAMPLE	103	473.47831200	21.51094649
SAMPLE	104	473.46617190	21.48925154

STAND DEV OF GROUP - 27.4722407411

80-25-29

FIGURE 11. SAMPLE DATA OF DME STABILITY TESTS (SHEET 3 OF 3)



80-25-30

FIGURE 12. PLOT OF DATA, STABILITY TESTS